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Tuning-CALOHEE Assessment Frameworks for the Subject Area of PHYSICS

The Tuning-CALOHEE Assessment Frameworks for ***Physics*** offers an important and novel tool for understanding, defining and visualising the requirements for any degree programme in the Subject Area or closely related to it. It shows, in a detailed but also general and flexible way, which competences should be developed by such a programme, giving useful indications about the relevant learning areas: not only core knowledge content, including theories and methodologies, but also skills for developing and applying that content, as well as the level at which the graduate will be able to operate meaningfully in his or her profession and, more broadly, in society. It distinguishes between the first and second cycle degree (Bachelor and Master) in the Subject Area, clarifying the progressive nature of the learning process, and showing the connections between levels of learning to be developed.

The CALOHEE Assessment Framework comprises easily read reference tables containing descriptors covering knowledge, skills and wider competences. These tables are an integral part of the *Tuning Guidelines and Reference Points 2018 for the Design and Delivery of Degree Programmes*, published separately. The Guidelines and Reference Points and the Assessment Framework have both been developed by an international working group of informed academics in the framework of the EU co-financed project Measuring and Comparing Achievements of Learning Outcomes in Higher Education in Europe (CALOHEE). They complement each other.

The advantages of being able to refer to an Assessment Framework are numerous. Such a framework provides:

- a widely accepted comprehensive overview of the key learning topics a degree programme can include, developed by an international group of experts, and validated by peers and other stakeholders;
- a range of up-to-date strategies, methodologies and approaches to learn, teach and assess the topics of learning, formulated in terms of learning outcomes.
- different stakeholder groups' insight into what could be usually covered in terms of learning in a particular subject area and a particular degree programme. Stakeholders include disciplinary experts, teaching staff, university and faculty management, professional organisations, employers, and (potential) students;
- a menu through which an individual degree programme at bachelor or master level can be composed and defined on the basis of motivated and articulated choices and a transparent decision making process;
- a fair indicator of the completeness and quality of a degree programme which allows for different institutional missions and profiles;
- a reliable mechanism for quality assurance based on a robust reference framework based on well-defined sets of measurable learning outcomes;
- a format for comparing different degree programmes in terms of profile, content and approach;
- a robust and articulated framework for developing comparable diagnostic assessments which offer reliable evidence regarding the strengths and weaknesses of a particular degree programme benchmarked against programmes with comparable missions and profiles.

CALOHEE's Assessment Framework can be seen as a general table providing a complete overview of the Subject Area in terms of measurable learning outcomes statements. These

statements, taken together, are much more precise than the more general Reference Points descriptors of the subject area involved. The focus in the framework is not only on 'what' to learn, but also on 'how' this 'what' can be learned. It represents the lowest, but at the same time most detailed level in the hierarchy of qualifications frameworks. This hierarchy starts with the overarching European frameworks, followed by national, sectoral and the subject area frameworks. As in the case of the subject area frameworks, the Assessment Framework organises its descriptors according to the categories knowledge, skills and competences distributed among the 'dimensions', which are seen as the main building blocks of the subject area. The descriptors, formulated in this way, provide structure and transparency: a general way to look at the Subject Area, through which specific programmes can be formulated.

While the general descriptors have the primary purpose of indicating the *type* and *level* of learning, in an Assessment Framework these are broken down using 'sub-descriptors' or 'subsets' which describe the key elements and topics that constitute each descriptor in greater detail. Although the general descriptors are often called learning outcomes, in practice they are much more competence statements. The real, utilizable, learning outcomes of a subject area are the sub-descriptors, because they meet the condition of being measurable, indicating not only a subject, but also context and complexity. The dimensions, sub-dimensions, descriptors and sub-descriptors together make an assessment framework which is complimented by an overview of the most appropriate learning, teaching and assessment strategies and approaches to achieve the intended learning outcomes. These can be formulated per sub dimension but are more often formulated for several related sub descriptors in order to avoid repetition.

The dimensions, descriptors, sub-dimensions and sub-descriptors appear in the Framework according to the following scheme:

Dimension	Knowledge descriptor	Skills descriptor	(Wider) Competence descriptor
1. Sub dim.	Sub-descriptor 1-1	Sub-descriptor 1-2	Sub-descriptor 1-3
2. Sub dim.	Sub-descriptor 2-1	Sub-descriptor 2-2	Sub-descriptor 2-3
3. Sub dim.	Sub-descriptor 3-1	Sub-descriptor 3-2	Sub-descriptor 3-3
4. Sub dim.	Sub-descriptor 4-1	Sub-descriptor 4-2	Sub-descriptor 4-3
5. Sub dim.	Sub-descriptor 5-1	Sub-descriptor 5-2	Sub-descriptor 5-3

According to the Tuning and CALOHEE philosophy, learning, teaching and assessment – in that order - should be fully aligned. A specific body of learning (knowledge, skills and competences), identified by the intended learning outcomes, is split into modules or units spread over the available learning period (e.g. academic years) in such a way that progression routes are established. Appropriate modes of learning, teaching and assessment are linked to each unit or module. These, of course, should fit the level of learning identified.

In CALOHEE, the highest level of learning is represented by the competence descriptor which is based on the knowledge and the skills that have been obtained and ideally practiced as part of the learning process. The competence descriptor can be compared to a 'competency framework' applied by employers or fields of employment. Such a framework describes in some detail which competences an employee in a particular occupation is expected to possess and be able to apply in practice. They are often reflected in job descriptions and job advertisements. Employment can range from research and analytical oriented positions to more practical ones: the competences required will vary, but will be related to the general competences linked to the Subject area.

An Assessment Framework should first and most of all be understood as a source of reference - inspiration and guidance - for modernising, revising and enhancing existing degree programmes and constructing new ones to meet the needs of the learners, preparing them appropriately for

their role in society, in terms both of employability and as citizens. For this reason, CALOHEE has developed a model in which the different aspects of the learning process are defined. The 'knowledge set of descriptors' is expected not only to cover core knowledge of the subject area but also related theories and methodologies. The 'skills set of descriptors' focusses on the skills/competences – generic and subject specific – which are relevant for applying knowledge. With regard to the generic skills /competences one normally thinks of such abilities as critical thinking, analysing and synthesising, creativity and originality and written and oral communication, but it is important to remember also value related competences such as ethical commitment.

The 'competence framework' as we have indicated covers not only preparation for operating successfully in the workplace, but also in society through effective civic, social and cultural engagement. To ensure that forming the competences necessary for such engagement constitutes an integral part of each degree programme, CALOHEE has developed a framework based on four dimensions which prepare for and underpin civic, social and cultural engagement. These have knowledge and skills descriptors as well as descriptors in the competence column. The dimensions chosen are:

1. Societies and Cultures: Interculturalism and conflict management;
2. Processes of information and communication;
3. Processes of governance and decision making;
4. Ethics, norms, values and professional standards.

To these dimensions the following descriptors have been added:

CALOHEE framework for Civic, social and cultural engagement

Dimension	Knowledge	Skills	Wider competences (Responsibility and Autonomy)
1. Society and Cultures	Demonstrate critical understanding of differences in and between societies and cultures	Identify, describe and analyse issues in and between societies and cultures	Demonstrate engagement by developing scenarios and alternatives for identifying best practices and interventions in the case of tensions and conflicts
2. Information and Communication	Demonstrate critical understanding of the processes of information and communication	Review and judge (mis)use of sources, data, evidence, qualities, intentions and transparency and expert opinions	Active contribution to societal debates using reliable data and information sources and informed judgements
3. Governance and decision making	Demonstrate critical understanding of the processes of governance and decision making	Apply and support agreed governing principles, norms and values regarding fairness, transparency, accountability, democracy and relevance in policy making processes	Active contribution to and with local and (inter)national communities, community groups, (political) organisations and pressure groups respecting agreed principles, norms and values
4. Ethics, norms, values and	Demonstrate critical	Understand and apply the processes of	Active contribution to upholding, promoting

standards	understanding of general ethical principles, norms and values and professional standards	decision making and the consequences of actions taking into account principles, norms, values and standards both from a personal and a professional standpoint.	and defending general ethical principles, norms, values and professional standards in governance, communication and cultural interaction.

Although presented here as a supplementary stand-alone framework, CALOHEE strategy is for the descriptors indicated in the table above to be integrated in the (sub-)descriptors of each subject area, at both first and second cycle. This also applies for the Assessment Framework presented here. The explanation and box above have been included to offer transparency regarding the inclusion of descriptors related to these topics.

The Guidelines and Reference Point document and the Assessment Framework for the subject area are both important instruments for course design, delivery and enhancement. According to Tuning and CALOHEE, they are suitable to becoming cornerstones of a new quality assurance system at programme level; a system that offers reliable evidence in terms of outcomes and performance based on descriptors developed and supported by the academics directly responsible for implementing degree programmes. Such a system can become an alternative to present-day overly bureaucratic models resulting from highly detailed but often abstract quality assurance procedures and processes, and including peer review system with its obvious shortcomings resulting from subjective personal judgements and opinions.

The ultimate ambition of the CALOHEE initiative is to develop a transnational multi-dimensional assessment model which allows for actual measuring and comparing of learning, taking into account the specific mission and profile of each degree programme, within its cultural and academic context. This model should offer sets of consistent test formats and items which make it possible the assessment of deep knowledge and understanding as well as high level skills. One could think of, for example, critical awareness, analysing and composition skills. An Assessment Framework is a key tool in this case because it offers a basis for identifying and developing the items to be tested. Although students' achievements will be individually assessed, the outcomes of the assessments will be generated at degree programme level (not at the individual student level), because the intention is – in line with traditional quality assurance systems – to diagnose whether the intended learning outcomes are actually achieved. In other words, does the programme offer what it has promised and does it meet the standards which have been agreed by the academic community? The Assessment Framework presented here should be understood as a planning tool, but also as a tool for answering this question.

A final note. This Assessment Framework is one of the outcomes of the work done by the Subject Area Group (SAG) in **Physics** which was established in the context of the CALOHEE project. The outcomes are presented in tables to facilitate readability and rapid comparison across the subject areas. The tables show in synthesis the consensus reached by a SAG after intense and lively discussions in the group. We hope that this Framework will be of interest to many, and look forward to receiving comments and suggestions from the stakeholders, in view of further improvement.

The Tuning-CALOHEE Management Team

CALOHEE - SAG in PHYSICS

Assessment Framework Template
First Cycle – LEVEL 6

Dimension 1: Theories and models			
	Knowledge	*Skills*	*Wider Competences (Responsibility and Autonomy)*
L6_1. Level descriptor Theories and models	**K6_1 Describe and explain the fundamental laws and theories in the various domains of physics including basic elements in modern physics.**	**S6_1 Use physics concepts from various domains of physics to analyse, explain and model physical phenomena; solve physical problems, identifying which laws are relevant for the given case/problem.**	**C6_1 Identify relevant theories that are required to understand a phenomenon or observation; recognize and illustrate the application of theories across a range of disciplines and real-life situations.**
Subset 1 L6_1.1 **Theories and phenomena**	K6_1.1 Name, describe and explain the fundamental laws, theories and relevant phenomena in various areas of physics.	S6_1.1 Determine which laws and theories are relevant for describing physical systems and apply these laws to explain observations and/or make predictions.	C6_1.1 Identify relevant theories that are required to understand a phenomenon or observation.
Subset 2 L6_1.2 **Applications of theories and models**	K6_1.2 Describe and explain how physics is used across a number of real-life applications.	S6_1.2 Apply basic elements of physics to various real-life applications.	C6_1.2 Identify which principles and theories are relevant in different real-life problems.

Dimension 2: Mathematical methods			
	Knowledge	*Skills*	*Wider Competences (Responsibility and Autonomy)*
L6_2. Level descriptor Mathematical methods	**K6_2 Show fundamental knowledge**	**S6_2 Apply suitable mathematical**	**C6_2 Adapt and connect**

	of standard mathematical tools such as calculus, algebra, geometry, numerical analysis, ...	**methods to solve problems, in some cases using appropriate numerical algorithms, at a level necessary to achieve the other program outcomes.**	**mathematical and numerical methods in different contexts, selecting and identifying the most appropriate ones to be used in solving problems.**
Subset 1 L6_2.1 **Mathematical tools**	K6_2.1 Recall and define mathematical tools.	S6_2.1 Apply correctly mathematical tools to solve problems, to model physical phenomena and to formulate approximations.	C6_2.1 Identify, interpret and justify the appropriate mathematical tool to model a specific problem.
Subset 2 L6_2.2 **Computational tools**	K6_2.2 Be familiar with basic computational tools and at least one programming language.	S6_2.2 Use basic software, programming language, computational tools and methods in physical and mathematical investigations.	C6_2.2 Evaluate the appropriate computational tools or methods to analyse, display results or model a specific problem.

Dimension 3: Experimental design and scientific investigation			
	Knowledge	*Skills*	*Wider Competences (Responsibility and Autonomy)*
L6_3. Level descriptor Experimental design and scientific investigation	**K6_3** **Be familiar with experimental methods, techniques and theories of measurement (instrumentation, calibration, data analysis, ...).**	**S6_3** **Carry out accurate experimental investigations using standard apparatus and following guidelines; apply standard mathematical and computational tools to analyse data.**	**C6_3** **Test explanations and theories by carrying out investigations in a logical and scientific manner, under supervision. This process includes the collection and analysis of data and a critical evaluation of the reliability, plausibility and significance of the outcomes.**
Subset 1 L6_2.1 I**nstrumentation**	K6_3.1 Name and describe standard physics instrumentation and be aware of its specifications (accuracy, sensitivity, ...), be familiar with standard	S6_3.1 Set up basic experimental arrangements, identify the specifications of the instruments and apply experimental procedures to gather data; be able	C6_3.1 Carry out investigations by selecting the best methodology after discussion with the supervisor, including choice of instrumentation where

	techniques for the processing of experimental data.	to estimate the anticipated order of magnitude of the results and to determine the uncertainties in their values.	appropriate, an awareness of health and safety issues and consideration of the reliability and accuracy of the outcomes.
Subset 2 L6_3.2 **Data analysis**	K6_3.2 Be acquainted with methods of data analysis.	S6_3.2 Organize and analyse data using the appropriate software.	C6_3.2 Analyse and synthesise data, critically evaluating the reliability, the correctness and the significance of the measurement process and of the derived results.
Subset 3 L6_3.3 **Scientific Methodology**	K6_3.3 Define the physical quantities involved in the situation and describe the inherent physical models or theories, showing a working knowledge of scientific methodology.	S6-3.3 Formulate and test hypothesis using standard experimental methods and use the results of the experiments to reformulate hypotheses.	C6_3.3 Conduct investigations under supervision, identifying the relevant theoretical framework, to test a formulated hypothesis and revise that hypothesis; iterate this process to find consistent explanations.
Subset 4 L6 _3.4 **Safety regulation**	K6_3.4 Know safety regulations of a laboratory.	S6_3.4 Follow safety regulations.	C6_3.4 Be aware of safety regulations and follow them; ask of them when introduced in a new experimental environmental.
Subset 5 L6_3.5 **Data record and experiment documentation**	K6_3.5 Know the methods of recording details of experimental activity and storing data.	S6_3.5 Keep a contemporaneous and systematic record of the successive steps of an experiment, including the acquisition of data.	C6_3.5 Keep track of the successive steps of an investigation and write a laboratory report.

Dimension 4: problem solving			
	Knowledge	*Skills*	*Wider Competences (Responsibility and Autonomy)*
L6_3. Level descriptor Problem solving	**K6_4** **Understand the problem, define a solving procedure and recall**	**S6_4** **Analyse and perform calculations independently,**	**C6_4** **Address problems choosing the appropriate mathematical,**

	necessary knowledge.	**both analytically and numerically; apply computational tools and programs for information processing, numerical calculus, simulation of physical processes and/or control of experiments.**	**numerical, computational and technological tools for modelling the problem situation, justify the choices made, monitor and evaluate the solving procedure and the result**
Subset 1 L6_2.1 **Problem framing**	K6_4.1 Outline the issues involved in problem and challenging situations.	S6_4.1 Frame, analyse and break down the problem in phases defining a suitable algorithmic procedure.	C6_4.1 Identify and compare various ways of approaching and resolving the problem, evaluating the most appropriate one, perceive and identify analogies between seemingly different situations in order to apply known procedure to solve problems.
Subset 2 L6_2.2 **Problem modelling and solution**	K6_4.2 Recall concepts and processes of physics and of other scientific subjects relevant for the problematic situation.	S6_4.2 Use/apply physics concepts and tools constructing/developing suitable model for representing the physical phenomena (modelling skills), evaluate the order of magnitude of the expected results (estimation skills), use one or more programming language and other useful software for data analysis (IT skills).	C6_4.2 Address problem situations choosing the appropriate mathematical, numerical, computational and technological tools.
Subset 3 L6_2.3 **Validation procedure**	K6_4.3 Define a validation procedure.	S6_4.3 Apply the different stages of the validation procedure, monitor and document the outcomes of the actions taken.	C6_4.3 Devise a plan, carry out the plan also accepting changes and admitting mistakes (perseverance and flexibility), look back to evaluate the process and the results.

Dimension 5: Scientific culture			
	Knowledge	*Skills*	*Wider Competences (Responsibility and Autonomy)*
L6_5. Level descriptor Scientific culture	**K6_5 Know and understand some examples of conceptual development of physics interpretations in historical and epistemological terms.**	**S6_5 Explain how historical and epistemological evolutions of physics have led to current scientific theories and how they have influenced technology and social culture.**	**C6_5 Identify and recognize common ideas and approaches in different areas of physics, also in relation to their historical and epistemological evolution.**
Subset 1 L6_5.1 **History of physics**	K6_5.1 Describe some examples of conceptual development of physics interpretations in historical terms.	S6_5.1 Explain how historical evolution of physics has led to current scientific theories and how it has influenced technology and social culture.	C6_5.1 Identify and recognize common ideas and approaches in different areas of physics, also in relation to their historical evolution; inspire one's own work from historical examples.
Subset 2 L6_5.2 **Epistemology**	K6_5.2 Describe some examples of conceptual development of physics in epistemological terms.	S6_5.2 Explain the consequences of dominant epistemological schemes on the development of scientific theories and how they have influenced technology and social culture.	C6_5.2 Outline the epistemological evolution of science following a frame of validation/invalidation of physics models/hypotheses.
Subset 3 L6_5.3 Sources of scientific information	K6_5.3 Know the procedures necessary to validate scientific works (committees of experts, peer reviewing of articles…) and know how to find trustful scientific information in libraries or on the Internet.	S6_5.3 Search for and use scientific information from physical and other technical literature, as well as any other sources, and duly quote it.	C6_5.3 Gather and evaluate information identifying relevant and reliable sources.

Dimension 6: Work ethic and integrity			
	Knowledge	*Skills*	*Wider Competences (Responsibility and Autonomy)*
L6_6. Level descriptor Work ethic and integrity	**K6_6 State and critically discuss general ethical principles, norms and values and professional standards.**	**S6_6 Apply ethical rules and rules of scientific conduct (scientific integrity) to behaviour in the profession.**	**C6_6 Make decisions in line with ethical norms and with regard to civic responsibility and actively contribute to societal debates using reliable data and information sources and informed judgements.**
Subset 1 L6_6.1 **Ethical rules in the profession**	K6_6.1 Recall the ethical rules and scientific integrity applied in the profession.	S6_6.1 Conduct processes of decision making and inspect the consequences of actions taking into account principles, norms, values and standards both from a personal and a professional standpoint.	C6_6.1 Actively contribute to upholding, promoting and defending general ethical principles, norms, values and professional standard in governance, communication and cultural interaction.
Subset 2 L6_6.2 **Awareness of professional actions impact**	K6_6.2 Recall examples when your actions as physicist affect health, environment and/or social issues on an ethical level.	S6_6.2 Estimate the impact of the technological applications of physical theories and models on individuals, environment and society.	C6_6.2 Be aware and accountable for his/her professional actions and make decisions in line with the ethical norms and social implications.

Dimension 7: Communication			
	Knowledge	*Skills*	*Wider Competences (Responsibility and Autonomy)*
L6_7. Level descriptor Communication	**K6_7 Describe the different methods and tools of communication.**	**S6_7 Communicate effectively to present complex information in a concise manner orally and in writing.**	**C6_7 Evaluate scientific material, communicate it orally and in writing in language appropriate for the audience.**
Subset 1	K6_7.1	S6_7.1	C6_7.1

L6_7.1 **Information sources**	Describe and discuss the processes of information and communication.	Evaluate the way in which sources of evidence, data, and expert opinions are used in various media.	Actively contribute to societal debates using reliable data and information sources.
Subset 2 L6_7.2 **Data representation**	K6_7.2 Describe different representations of data (words, graphs, tables, animations).	S6_7.2 Use different representation of data.	C6_7.2 Compare and identify the appropriate representation of data for presentations to peer groups.
Subset 3 L6_7.3 **Means of communication**	K6_7.3 Describe and explain the role of different means of communication (scientific magazines, books, newspapers, videos, web, …).	S6_7.3 Produce simple scientific reports and oral presentations, using appropriate technical language.	C6_7.3 Identify and choose the appropriate writing or oral style according to the context and communicative goals (laboratory report, dissertation, scientific articles…).
Subset 4 L6_7.4 **Technical English**	K6_7.4 Demonstrate a working knowledge the English language at the level necessary for basic physics communication.	S6_7.4 Read, speak, write in technical English.	C6_7.4 Study and communicate specific physics topics in technical English (minimum B1 level of Common European Framework of Reference for Languages).

Dimension 8: Project Management and Teamwork			
	Knowledge	*Skills*	*Wider Competences (Responsibility and Autonomy)*
L6_8. Level descriptor Project Management and Teamwork	**K6_8** **Know strategies for project work and demonstrate attitude to work collaboratively.**	**S6_8** **Organize and complete a simple project individually or in team.**	**C6_8** **Identify and implement an appropriate way to plan, design a simple project, contribute constructively in a team, take responsibility and demonstrate engagement.**
Subset 1 L6_8.1	K6_8.1 Recall strategies for planning,	S6_8.1 Plan a simple project using the	C6_8.1 Take responsibility, establish and

Project management tools	organizing, checking progress, evaluating results of a project.	appropriate tools, set targets, work independently within the defined time boundaries.	prioritize project goals, manage simple individual/group projects.
Subset 2 L6_8.2 **Governance and decision making**	K6_8.2 Understand differences in and between individuals and (working) cultures.	S6_8.2 Identify, describe and analyse issues in and between individuals and (working) cultures.	C6_8.2 Demonstrate engagement by developing scenarios and alternatives for identifying best practices and interventions in the case of tensions and conflicts
Subset 3 L6-8.3 **Teamwork**	K6_8.3 Evaluate different viewpoints, receiving evaluations and feedback and giving feedback to peers.	K6_8.3 Collaborate effectively and participate in a team (listen, share opinions and participate in conversation and/or discussion activities, give constructive feedback to peers), take responsibility for his/her tasks(s) in a group.	K6_8.3 Recognize his/her personal competences and strengths/weaknesses with respect to work in a team, participate in a respectful way, appreciating the views of others, taking direction, accepting criticism, using feedback, and enhancing group performance.

Dimension 9: Professional development			
	Knowledge	*Skills*	*Wider Competences (Responsibility and Autonomy)*
L6_9. Level descriptor Professional development	**K6_9. Know which competences, knowledge, skills and qualifications are needed to pursue further studies (career goals) and relate them with the personal strengths and weaknesses.**	**S6_9 Organize the personal learning process, evaluate personal work, consult experts for information and support when appropriate.**	**C6_9 When they are introduced, enter new fields of theoretical or applied physics through a positive attitude, possibly with an independent study and a significant degree of autonomy and responsibility; evaluate the development of personal learning; acquire additional qualifications for career.**

Subset 1 L6_9.1 **Professional requirements**	K6_9.1 Know which competences, and qualifications are needed to pursue further studies (career goals).	S6_9.1 Find the necessary information to pursue further studies (career).	C6_9.1 Use ICT, literature search and computational skills for gaining new knowledge and skills through an autonomous, independent learning or acquiring additional qualifications for career.
Subset 2 L6_9.2 **Personal capacities and attitudes**	K6_9.2 Know and understand strengths and weaknesses of personal skills and qualifications in order to make conscious (informed) decisions for further studies.	S6_9.2 Reflect on the approach of learning, performing tasks and assignments and how to improve.	C6_9.2 Identify gaps in personal knowledge, skills and competences and undertake appropriate actions to improve personal competences.

CALOHEE - SAG in PHYSICS

Assessment Framework Template
First Cycle – LEVEL 7

Dimension 1: Theories and models			
	Knowledge	*Skills*	*Wider Competences (Responsibility and Autonomy)*
L7_1. Level descriptor Theories and models	**K7_1 Describe and explain laws and theories in the various domains of physics and acquire a deeper knowledge in at least one of the specialised cores of modern physics.**	**S7_1 Use physics concepts in various domains of physics to analyse, explain and model physical phenomena and to solve complex problems, identifying which laws are relevant for the given case/problem.**	**C7_1 Identify relevant theories that are required to understand a phenomenon or observation; recognize the limitations of current knowledge and demonstrate ability to use sources of new knowledge; integrate concepts across a variety of areas.**
Subset 1 L7_1.1 **Theories and phenomena**	K7_1.1 Name, describe and explain the fundamental laws, theories and relevant phenomena in various areas of physics with a deeper knowledge in at least one of the specialised cores of modern physics.	S7_1.1 Determine which laws and theories are relevant for describing a physical system and apply them for explaining observations and/or make predictions.	C7_1.1 Identify relevant theories that are required to understand a phenomenon or observation.
Subset 2 L7_1.2 **Applications of theories and models**	K7_1.2 Describe and explain how advanced physics is used across a number of real-life applications, also possibly in the context of a different discipline.	S7_1.2 Apply advanced elements of physics to various real-life applications and in the context of a different discipline.	C7_1.2 Identify principles and theories relevant to different real-life problems and in a variety of disciplines and apply them to the solution of those problems.

Dimension 2: Mathematical methods			
	Knowledge	*Skills*	*Wider Competences (Responsibility and Autonomy)*
L7_2. Level descriptor Mathematical methods	**K7_2 Show extensive knowledge of standard mathematical tools such as calculus, algebra, geometry, numerical analysis, ...**	**S7_2 Apply suitable mathematical methods to solve problems; use appropriate numerical algorithms where necessary.**	**C7_2 Adapt and connect mathematical and numerical methods in different contexts, selecting and identifying the most appropriate ones to be used in solving problems.**
Subset 1 L7_2.1 **Mathematical tools**	K7_2.1 Recall and define mathematical tools (e.g. differential and integral calculus, algebra, analytic functions of real and complex variables, vectors and matrices, vector calculus, ordinary and partial differential equations, statistics, Fourier methods, groups theory, etc.).	S7_2.1 Apply mathematical tools to solve complex problems, to model physical phenomena and to formulate approximations, interpolations and extrapolations.	C7_2.1 Identify, interpret and justify the appropriate mathematical model of a specific problem.
Subset 2 L7_2.2 **Computational tools**	K6_2.2 Be familiar with computational tools and at least one programming language.	S7_2.2 Use appropriate software, programming language, computational tools and methods in physical and mathematical investigations.	C7_2.2 Evaluate the appropriate computational tools or methods to analyse, display results or model a specific problem emerged from a real context.

Dimension 3: Experimental design and scientific investigation			
	Knowledge	*Skills*	*Wider Competences (Responsibility and Autonomy)*
L7_3. Level descriptor Experimental design and scientific investigation	**K7_3 Know experimental methods, techniques and theories of measurement (instrumentation,**	**S7_3 Carry out accurate experimental investigations independently; apply standard**	**C7_3 Test explanations and theories by carrying out investigations in a logical and scientific manner.**

	calibration, data analysis, ...)	**mathematical and computational tools to analyse data**	**This process includes the collection and analysis of data and a critical evaluation of the reliability, plausibility and significance of the outcomes**
Subset 1 L7_3.1 I**nstrumentation**	K7_3.1 Name and describe physics instrumentation and its specifications (accuracy, sensitivity, ...), know different techniques for the processing of experimental data.	S7_3.1 Set up bespoke experimental arrangements, identify the specifications of the instruments and apply experimental procedures to gather data; be able to estimate the anticipated order of magnitude of the results and to determine the uncertainties in their values.	C7_3.1 Carry out investigations by selecting the best methodology, including choice of instrumentation, an awareness of health and safety issues and consideration of the reliability and accuracy of the outcomes.
Subset 2 L7_3.2 **Data analysis**	K7_3.2 Be familiar with methods of data analysis.	S7_3.2 Organise and analyse data (also big data) using the appropriate software.	C7_3.2 Analyse and synthesise data, critically evaluating the reliability of the measurement process, the correctness and the significance of the derived result.
Subset 3 L7_3.3 **Scientific Methodology**	K7_3.3 Define the physical quantities involved in the situation and describe the inherent physical models or theories; describe the scientific process necessary to validate a theory or a model showing a working knowledge of scientific methodology.	S7-3.3 Formulate and test hypotheses, using experimental methods and use the results of the experiments to reformulate hypotheses; assemble and conduct an advanced textbook experiment independently.	C7_3.3 Conduct investigations, identifying the relevant theoretical framework, to test a formulated hypothesis and revise that hypothesis; iterate this process to find consistent explanation, evaluating the process reliability.
Subset 4 L7 _3.4 **Safety regulation**	K7_3.4 Know safety regulations of a laboratory.	S7_3.4 Follow safety regulations.	C7_3.4 Be aware of safety regulations and follow them, ask of them when introduced in a new experimental environment.
Subset 5	K7_3.5	S7_3.5	C7_3.5

L7_3.5 **Data record and experiment documentation**	Know the methods of recording details of experimental activity and storing data.	Keep a contemporaneous and systematic record of the successive steps of an experiment, including the acquisition of data.	Systematically keep track of the successive steps of an investigation and write a clear and complete laboratory report.

Dimension 4: Problem solving			
	Knowledge	*Skills*	*Wider Competences (Responsibility and Autonomy)*
L7_4. Level descriptor Problem solving	**K7_4 Understand the problem and define a solving procedure.**	**S7_4 Analyse and perform calculations independently, both analytically and numerically; apply and design computational tools and programs for information processing, numerical calculus, simulation of physical processes and/or control of experiments.**	**C7_4 Address real world problem situations choosing the appropriate mathematical, numerical, computational and technological tools; perceive and identify analogies between different situations in order to apply or adapt known procedure to solve problems.**
Subset 1 L7_4.1 **Problem framing**	K7_4.1 Outline the issues, involved in problematic, challenging situations.	S7_4.1 Frame, analyse and break down the problem in phases defining a suitable algorithmic procedure.	C7_4.1 Identify and compare various ways of approaching and resolving the problem, evaluating the most appropriate one, perceive and identify analogies between seemingly different situations in order to apply known procedure to solve problems.
Subset 2 L7_4.2 **Problem modelling and solution**	K7_4.2 Recall concepts and processes of physics and of other scientific subjects relevant for the problematic situation.	S7_4.2 Use/apply physics concepts and tools constructing/developing suitable model for representing the physical phenomena (modelling skills), evaluate the order of magnitude of the expected results (estimation	C7_4.2 Address real world problem situations choosing the appropriate mathematical, numerical, computational and technological tools, using and integrating ideas and approaches transversally across different

		skills), use appropriate software or write their own code (IT skills).	subjects (physics in other context, other disciplines in physics context).
Subset 3 L7_7.3 **Validation procedure**	K7_4.3 Define a validation procedure.	S7_4.3 Apply the different stages of the validation procedure, monitor and document the outcomes of the actions taken.	C7_4.3 Devise a plan, carry out the plan also accepting changes and admitting mistakes (perseverance and flexibility), monitor and evaluate the process and the results.

Dimension 5: Scientific culture			
	Knowledge	*Skills*	*Wider Competences (Responsibility and Autonomy)*
L7_5. Level descriptor **Scientific culture**	**K7_5** Know and understand some examples of conceptual development of physics interpretations in historical and epistemological terms.	**S7_5** Explain how historical and epistemological evolutions of physics has led to current scientific theories and how it has influenced technology and social culture.	**C7_5** identify and critically discuss common ideas and approaches in different areas of physics, also in relation to their historical and epistemological evolution.
Subset 1 L7_5.1 **History of physics**	K7_5.1 Illustrate some examples of conceptual development of physics interpretations in historical terms.	S7_5.1 Explain how historical evolution of physics has led to current scientific theories and how it has influenced technology and social culture.	C7_5.1 Identify and critically discuss common ideas and approaches in different areas of physics, also in relation to their historical evolution; inspire one's own work from historical examples.
Subset 2 L7_5.2 **Epistemology**	K7_5.2 Illustrate some examples of conceptual development of physics in epistemological terms.	S7_5.2 Explain the consequences of dominant epistemological schemes on the development of scientific theories and how they have influenced technology and social culture.	C7_5.2 Critically discuss the epistemological evolution of science following a frame of validation/invalidation of physics models/hypotheses. Assess the rigorousness of a

			scientific approach.
Subset 3 L7_5.3 **Sources of scientific information**	K7_5.3 Know the procedures necessary to validate scientific works (committees of experts, peer reviewing of articles…) and know how to find trustful scientific information in libraries or on the Internet.	S7_5.3 Search for and use scientific information from physical and other technical literature, as well as any other sources, and duly quote it.	C7_5.3 Gather and evaluate information identifying relevant and reliable sources.

Dimension 6: Work ethic and integrity			
	Knowledge	*Skills*	*Wider Competences (Responsibility and Autonomy)*
L7_6. Level descriptor **Work ethic and integrity**	**K7_6** **State and critically discuss general ethical principles, norms and values and professional standards.**	**S7_6** **Apply ethical rules and rules of scientific conduct (scientific integrity) to behaviour in the profession.**	**C7_6** **Make decisions in line with ethical norms also in research environments and actively contribute to societal debates using reliable data and defend general ethical principles, norms, values and professional standard with local and (inter)national communities, community groups, (political) organisations.**
Subset 1 L7_6.1 **Ethical rules in the profession**	K7_6.1 State and critically discuss general ethical principles, norms and values and professional standards.	S7_6.1 Conduct processes of decision making and inspect the consequences of actions taking into account principles, norms, values and standards both from a personal and a professional standpoint.	C7_6.1 Actively contribute to upholding, promoting and defending general ethical principles, norms, values and professional standard in governance, communication and cultural interaction.
Subset 2 L7_6.2	K7_6.2 Recall examples when your	S7_6.2 Estimate the impact of the	C7_6.2 Take responsibility for his/her

Awareness of professional actions impact	actions as physicist affect health, environment and/or social issues on an ethical level.	technological applications of physical theories and models on individuals, environment and society.	professional actions and make decisions in line with the ethical norms and social implications.

Dimension 7: Communication			
	Knowledge	*Skills*	*Wider Competences (Responsibility and Autonomy)*
L7_7. Level descriptor Communication	**K7_7 Describe the different channels and tools of communication and their limitations.**	**S7_7 Communicate effectively to present complex information in a concise manner orally and in writing and using ICT and technical language appropriate for the audience.**	**C7_7 Evaluate scientific material and communicate it to a variety of audiences to inform, influence and debate using various techniques and technical language appropriate for the audience.**
Subset 1 L7_7.1 **Information sources**	K7_7.1 Describe the process by which information is communicated and the purposes of that communication.	S7_7.1 Critically evaluate the use and misuse of evidence, data, expert opinion in various media.	C7_7.1 Actively contribute to societal debates using reliable data and information based on reliable sources and informed judgements.
Subset 2 L7_7.2 **Data representation**	K7_7.2 Describe different representations of data (words, graphs, tables, animations).	S7_7.2 Use different representations of data.	C7_7.2 Compare and appraise the appropriate representation of data and construct a logical argument or presentation based upon it.
Subset 3 L7_7.3 **Means of communication**	K7_7.3 Identify and describe the role of different means of communication (scientific magazines, books, newspapers, video, web, …)	S7_7.3 Distinguish among different communication channels, produce simple scientific reports and oral presentations, using technical language appropriate for the audience.	C7_7.3 Identify and use the appropriate level, writing or oral style according to the context and communicative goals (laboratory report, dissertation, popular article, ...), using reliable sources.

Subset 4 L7 _7.4 **Technical English**	K7_7.4 Use the English language at the level necessary for physics communication.	S7_7.4 Read, speak, write and participate in discussions fluently in technical English.	C7_7.4 Study and communicate specific physics topics in technical English (minimum B2 level of Common European Framework of Reference for Languages), differentiating the language according to the audience and purpose of the communication.

Dimension 8: Project management and teamwork			
	Knowledge	*Skills*	*Wider Competences (Responsibility and Autonomy)*
L7_8. Level descriptor Project Management and Teamwork	**K7_8** **Know appropriate project management tools and demonstrate attitude to perform in a team.**	**S7_8** **Engage productively in an individual or group project.**	**C7_8** **Identify and implement the most appropriate way to plan, design a project, perform technical and/or supervisory functions related to products, services, operations or processes. contribute constructively in or lead a team, take responsibility and demonstrate engagement.**
Subset 1 L7_8.1 **Project management tools**	K7_8.1 Determine appropriate project management tools (planning, organizing, checking progress, evaluate results).	S7_8.1 Manage a project using appropriate tools, set targets, work independently within defined boundaries.	C7_8.1 Take responsibility, set priorities, establish clearly objectives and goals of a project, manage individual/group projects, evaluate project outcomes.
Subset 2 L7_8.2 **Governance and decision making**	K7_8.2 Identify differences among individuals, determine their strengths and weaknesses, adapt to different (work) cultures.	S7_8.2 Identify, describe and analyse issues and potential conflicts in and between individuals.	C7_8.2 Identify best practices and interventions in the case of tensions and/or conflicts, operate in a diverse group, assess strengths and weaknesses of individuals.

Subset 3 L7_8.3 **Teamwork**	K7_8.3 Accumulate various viewpoints, provide feedback and collaborate effectively in a team.	S7_8.3 Contribute effectively to a team (listen, share opinions and participate in conversation and/or discussion activities, give constructive feedback), take responsibility for his/her task(s) in a group.	C7_8.3 Recognize personal competences and strengths/weaknesses (and those of others) with respect to work in a team, participate in a respectful way, contribute constructively in a structured team environment across disciplines, appreciating the views of others, taking direction, accepting criticism, using feedback, and enhancing group performance.

Dimension 9: Professional development			
	Knowledge	*Skills*	*Wider Competences (Responsibility and Autonomy)*
L7_9. Level descriptor **Professional development**	**K7_9** **Know which competences, knowledge, skills and qualifications are needed for the desired field of employment and relate them with the personal strengths and weaknesses.**	**S7_9** **Identify personal strengths and weaknesses and, when appropriate, to find the necessary training opportunities.**	**C7_9** **Evaluate the development of personal learning; enter new fields of theoretical or applied physics through a positive attitude, with an independent study, autonomy and responsibility; take appropriate actions to adapt to changes in the professional career.**
Subset 1 L7_9.1 **Professional requirements**	K7_9.1 Know which competences, and qualifications are needed for a given field of employment.	S7_9.1 Use study and research skills, ICT, literature search and computational skills for gaining new knowledge and skills.	C7_9.1 Remain aware of industrial, regulatory and societal change, which will impact on chosen specialization; learn to act in variable and unfamiliar learning contexts; learn to manage learning tasks independently,

			professionally and ethically.
Subset 2 L7_9.2 **Personal capacities and attitudes**	K7_9.2 Know strengths and weaknesses of personal skills and qualifications in order to make conscious (informed) decisions for further career.	S7_9.2 Reflect on the personal knowledge, skills and attitudes, relate this with the conditions for a given career and, when appropriate, find the necessary training opportunities.	C7_9.2 Identify gaps in personal knowledge, skills and competences and undertake appropriate actions to adapt to changes in the professional career.