TUNING SUMMARY
or
COMMON REFERENCE POINTS

for

PHYSICS

In the following pages you will find the standard Tuning Subject Template as filled in by the Physics SAG.

Important editing Nota Bene:

1. **The references are in red colour on a yellow background and they are mainly targeted to the printed version of the Physics Tuning Summary. The web version should make appropriate e-links.**

2. **The references / links to the two following documents**

   - **the complete Tuning map of professions**
   - **the complete Physics paper on the development of subject specific competences**

   are not precise enough, since their location in the Tuning materials has not yet been decided / finalised.

3. **The Six Sections of the Template have been numbered progressively, since that would make easier possible referencing and comparison with other SAGs' summaries. A subsection numbering is also tried. Moreover the Section Title was written in capital letters.**

4. **We added an ANNEX I, where we present some remarks about the relation of our Physics specific competences with the Dublin Descriptors. The Dublin Descriptors are shortly introduced and linked to our competences already in the Section 3 (i.e. the section about Learning outcomes & competences)**

Template for summary of Tuning subject area findings

PHYSICS

(updated 19.05.2005)

1. INTRODUCTION TO THE SUBJECT AREA

The body of knowledge, which is broadly named **physical sciences,** generates several degree-courses in the European Universities. Names such as

> *Physics, Astronomy, Theoretical Physics, Applied Physics, Engineering Physics, Biophysics, Physical Oceanography, Geophysics, Materials Sciences, Environmental Physics, etc.*

can easily be found.

The *pure* degree-course is the **Physics degree-course**. In some of the above degree-courses, other subjects may be quite relevant together with physics, e.g. chemistry in Materials Sciences. All the above degrees always and heavily rely on a good mathematical background, which is offered, often since scratch, within the degree course itself. Continental universities traditionally offered to the Physics students a very deep and thorough approach to mathematics teaching/learning.

Two main approaches exist, when designing a Physics programme:

- The initial years of the programme are common to the subjects of physics, mathematics, chemistry, etc. and the students make the choice of the main subject only later (e.g. at the third year, this is the case of Copenhagen).
- The whole degree-course is focused on "physics" from the beginning.

Physics, being the *most basic* after Mathematics among the Natural Sciences, is usually offered within the Faculty of Natural Sciences; this is the case of many continental universities. Another quite usual setting is the offer of the degree-course within a Physics Department, where the physicists' community lives. In other cases the offer of a degree-course in Applied Physics or similar occurs within a Faculty of Engineering or a Department of Applied Physics. The physicists' community often offers **units in Physics** for a number of quite different Degree-courses of the same university (see below).

The Tuning network in Physics reflects this complexity of scenarios. Nevertheless experience showed that meaningful common reference points can be obtained even with this apparently not homogeneous sample of institutions.

2. DEGREE PROFILE(S) AND OCCUPATIONS

For a list of possible degrees, do see the introduction above. We give here the profile and occupations for the Physics Degree

2.1 Typical degrees offered in the subject area:

NB for a more detailed description of the Physics core knowledge see Ref. [1], **pages 185-211**. Our analysis[1] shows that identification of a common core knowledge is certainly possible in Europe in the 1st cycle degree courses in Physics, but it becomes rather questionable in the 2nd cycle, essentially because each institution focus on a different specialisation (see Fig 2 **at page 197** of Ref. [1]).

- First cycle in Physics
  - Knowledge of mathematics and related subjects (basic mathematics; mathematical methods for physics; computing; numerical analysis)
  - Knowledge of basic physics [introduction to physics; classical physics (including demonstrations); quantum physics (including demonstrations); laboratory]
  - Knowledge of basic elements in theoretical physics (analytical mechanics; classical electromagnetism, relativity, etc.; quantum mechanics / theory; statistical physics)
  - Knowledge of elements of applied physics and related subjects (chemistry; electronics & related; etc.)

[1] which is to be considered as preliminary, because of the present transitory phase concerning the implementations of the several national Bologna Reforms.

- Knowledge of basic elements in modern physics (atomic, nuclear and sub-nuclear, solid state, astrophysics)
- Small *intermediate* or *final* physics project(s), depending on the institution
- Other essential elements, in varying amount depending on the institution (e.g. Knowledge of topics «*chosen from list(s)*»; presenting a lab report; taking active part in a seminar)
- Some knowledge/abilities in non-standard subjects, in varying amount depending on the institution (e.g. vocational training, skills development, placement, etc.)
- Knowledge of topics identified through a «*completely free choice*» of the student.

- Second cycle in Physics
  - Advanced knowledge of theoretical physics (analytical mechanics; classical electromagnetism, relativity, etc.; quantum mechanics / theory; statistical physics)
  - Deep knowledge of mathematics and related subjects (mathematical methods for physics; computing; numerical analysis)
  - Knowledge of specialised core(s) of modern physics (atomic, nuclear and sub-nuclear, solid state, astro-physics)
  - Knowledge of other specialised subjects (biophysics, medical physics, meteorology, environment physics, oceanography) depending of the institution and profile of specialisation
  - Ability to solve problems in comprehensive physics (depending on the institution)
  - Final year physics project / thesis and development of the corresponding research skills
  - Other essential elements, in varying amount depending on the institution (e.g. Knowledge of topics «*chosen from list(s)*»; Ability to master advanced laboratory practice; Presenting a lab report; Taking active part in a seminar).
  - Some knowledge/abilities in *non-standard subjects*, in varying amount depending on the institution (e.g. vocational training, skills development, placement, etc.)
  - Knowledge of topics identified through a «*completely free choice*» of the student.

- Third cycle in Physics

- Coursework (depending on the institution, but in any case limited in time)
- Original research work, usually carried out in a research group. The supervised doctoral research mostly leads to a written dissertation, to be assessed by an appropriate Examination Board, and/or to publications in refereed journals

2.2 Typical occupations of the graduates in the subject area

NB the complete Tuning map of professions is given **elsewhere in this same book / site.**

- First cycle in Physics

At present (may 2005) there is very limited experience in job access after the first cycle degree in physics, since this is a new degree in most European countries

Sub discipline / Field of specialization	Category / Group of professions	List of professions related to specialization
PHYSICS bachelor	Technical jobs in governmental organizations or private sector (banking, insurance companies, services) at intermediate decision levels	• Placements and positions in industrial companies • Technical assistants • Informatics, computer science, information technology • Jobs in Insurance companies and banking (software, development, planning assistants) • Self employment • Meteorologist* • Metrologists

*The access qualifications for the different classes of meteorologists are normally regulated at national level

- Second cycle in Physics (and Integrated[2] Degrees)

Since the second cycle allows diversity in the specialisation fields of the final graduates, we list several sub-characterisation of the second cycle degree in Physics. In each sub-area the most relevant specific competences (not listed here, but see a general description in section 3 below) may have different relevance or weight.

[2] *i.e.* a long one-tier first degree, without intermediate exit, replacing the two-tier degree scheme of Bachelor's plus Master's degrees.

Sub discipline / Field of specialisation	Category / Group of professions	List of professions related to specialisation
PHYSICS / EXPERIMENTAL PHYSICS	• Physicists in governmental organizations or private sector • Research, innovation and development related professions • High Technology sector • Engineering • Metrology /quality control related professions • Technical consultancy • Banking	• Physicist (in universities, research institutes) • Research assistants in universities, institutes, industries. • Industrial physicist (in companies dealing with microelectronics, software, tele-communications, opto-electronics, optics, materials) • Self employment • Technical consultants • Metrologists • Quality controllers • Technical jobs in radiation protection services
PHYSICS / THEORETICAL PHYSICS	• Physicists in governmental organisations or private sector • Research, innovation and development related professions • Banking and Insurance sector	• Physicists (in universities, research institutes) • Research assistants in universities, institutes, industries. • Industrial physicists: microelectronics, software development, telecommunications, optics, information technologies, etc • Computer science related professions (software development, economical and finance analysis and modelling) • Self employment • Technical consultants
APPLIED PHYSICS / TECHNICAL PHYSICS / ENGINEERING PHYSICS / INFORMATIC PHYSICS	• Physicists in governmental organizations or private sector • Research and development related professions in governmental organizations or private sector • Engineering • Metrology / quality control related professions • High Technology sector	• Industrial physicist: microelectronics, software, telecommunications, opto-electronics, optics, materials • Physicist (in universities, research institutes) • Engineers • Research assistants in universities, Institutes, industries. • Computer science related professions Metrologists • Quality engineers • Positions in information technology sector in industry, banks, insurance companies (software development, economical and finance analysis and modelling) • Medical physicist (radiotherapy, radiology and radiation protection)* • Technical jobs in radiation protection services • Technical consultant • Self employment
BIOPHYSICS	• Governmental organizations or private sector	• Research assistant in universities, institutes, industry • Positions in insurance companies • Biophysicists • Technical consultant • Self-employement
MEDICAL PHYSICS*	• Positions in Medical physics: hospitals, governmental institutions for medical care and health security	• Medical Physicist (radiotherapy, radiology and radiation protection)* • Research assistant in universities, institutes, industry • Positions in insurance companies, self-employed businesses • Technical consultant

PHYSICS AND DIDACTICS or PHYSICS and a SECOND SUBJECT, at same academic level, plus DIDACTICS	• Teaching**	• Physics teachers at Secondary and High Schools • Teachers in private organizations
PHYSICS / METEOROLOGY AND PHYSICS OF THE EARTH AND THE ENVIRONMENT / OCEANOGRAPHY	• Physicists in governmental organizations or private sector	• Research assistants in universities, institutes, public and/or private agencies, industries. • Meteorologists*** • Geophysicists • Oceanographers • Technical consultants • Self employment

* Medical Physicist is a regulated profession in most European countries.

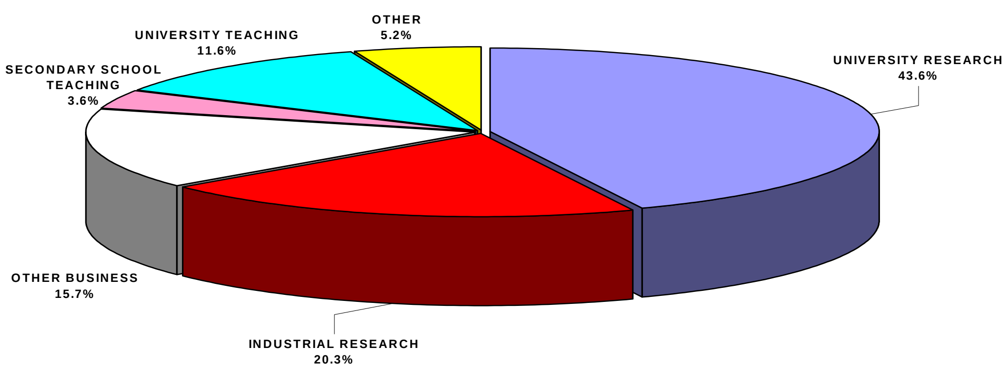
**The route to qualifications, which enable to teach, varies substantially across Europe. In some countries teaching qualifications in Physics are obtained independently of the University physics degree. In some others Physics Teaching is a specialization of a physics degree or even a completely independent degree. So the situation described in the table is not universal.

***The access qualifications for the different classes of meteorologists are usually regulated at national level

- Third cycle in Physics

  Some "old" data are given here just for orientating purposes. **This issue is being further explored and updated under Tuning 3.**

DESTINATION OF PHYSICS DOCTORAL GRADUATES (EUPEN survey 1999, ref [2])



2.3 Role of subject area in other degree programmes

In many universities, the physicists' community offers units in Physics for a number of degree-courses, which are quite different from Physics. Indeed, Physics units are needed as an essential element for the degree-courses in mathematics, chemistry, geology, biology, etc.(all of them within the area of Natural Sciences), for all the degree-courses of the Engineering area and for several of the degree-courses of the faculties of Medicine, Veterinary Medicine, Agricultural Sciences, Pharmacology, History and Philosophy, etc.). Within this context different organisational models are at work. Possible – non exhaustive – examples are:

- the Physics Department serves all the many different interested degree-courses of the given university;
- the academics, who are physics teachers in other subject areas, belong to Departments, which are different from the Physics Department and are closely related to the subject of the degree course.

As an example, European wide meetings of the physics teachers for the Engineering area are convened regularly.

3. LEARNING OUTCOMES AND COMPETENCES – LEVEL CYCLE DESCRIPTORS

The Physics relevant learning outcomes are given under Degree profile (see appropriate section above). Here below we focus on competences and levels.

3.1 Generic competences

The generic competences' importance has been ranked by the Physics academics independently of the cycle, on the basis of the questionnaire at **page 278 of Ref. [1]**, yielding the following order:

Ranking	GENERIC COMPETENCES
1	Basic Knowledge of the field
2	Capacity for Analysis and synthesis
3	Capacity to learn
3	Creativity
5	Applying knowledge in practice
6	Adaptability
6	Critical and self critical abilities
8	Basic knowledge of the profession
8	Research skills
10	Interdisciplinarity
11	Oral and written communication
12	Ethical commitment
12	Interpersonal skills
14	Knowledge of a second language
15	Elementary computing
15	Decision making
17	Diversity and multi-culture

3.2 Subject specific competences

The importance of the subject specific competences was rated separately for the first and the second cycle by the Physics academics (on a scale from 1 to 4), on the basis of the questionnaire shown at **pages 294-297 of Ref. [1]**. The actual rating orders are given below. For more details, see **pages 171-185 of Ref. [1]**.

Our competences and their relative importance in the two cycles describe what is to be in general achieved by Physics students after graduation. Our competences link very well with the Dublin Descriptors, i.e. the more general cycle descriptors recently adopted as one of the founding elements of the European Qualification Framework. Indeed, each of our listed subject specific competences can easily be assigned to one of the five dimensions or elements, which characterise the Dublin Descriptors. This is shown in the tables below, fourth column, where the appropriate Dublin Descriptor dimension is identified for each Physics subject specific competence, according to the following label assignments to the five dimensions.

A Knowledge and understanding
B Applying knowledge and understanding
C Making judgements
D Communications skills
E Learning skills

As to further remarks about the link between our competences and the Dublin Descriptors, see Annex I.

- First cycle

RATING OF IMPORTANCE ORDER	**SHORT NAME**[3] OF THE SUBJECT SPECIFIC COMPETENCE	**EXTENDED DESCRIPTION OF THE COMPETENCE** *on completion of a first cycle degree in Physics, the student should:*	**DUBLIN DESCRIPTOR LABEL**
1	Problem solving skills	be able to evaluate clearly the orders of magnitude in situations which are physically different, but show analogies, thus allowing the use of known solutions in new problems	B
2	Theoretical understanding	have a good understanding of the most important physical theories (logical and mathematical structure, experimental support, described physical phenomena)	A
3	Mathematical skills	be able to understand and master the use of the most commonly used mathematical and numerical methods	A-B
4	Deep knowledge	have a deep knowledge of the foundations of modern physics, say quantum theory, etc .	A
5	Experimental skills	have become familiar with most important experimental methods and be able to perform experiments independently, as well as to describe, analyse and critically evaluate experimental data	B
6	Modelling & Problem solving skills	be able to identify the essentials of a process / situation and to set up a working model of the same; be able to perform the required approximations; i.e. critical thinking to construct physical models	B
7	Prob. solving and computer skills	be able to perform calculations independently, even when a small PC or a large computer is needed, including the development of software programmes	B
8	Physics culture	be familiar with the most important areas of physics and with those approaches, which span many areas in physics	A
9	Basic & Applied Research	acquire an understanding of the nature and ways of physics research and of how physics research is applicable to many fields other than physics, e.g. engineering; be able to design experimental and/or theoretical procedures for: (i) solving current problems in academic or industrial research; (ii) improving the existing results	A-B-C
10	Literature search	be able to search for and use physical and other technical literature, as well as any other sources of information relevant to research work and technical project development. Good knowledge of technical English is required.	E
11	Learning ability	be able to enter new fields through independent study	E
12	Modelling	be able to adapt available models to new experimental data	B
13	Human / professional skills	be able to develop a personal sense of responsibility, given the free choice of elective/optional courses; be able to gain professional flexibility through the wide spectrum of scientific techniques offered in the curriculum	A-B
14	Absolute standards	have become familiar with "*the work of genius*", i.e. with the variety and delight of physical discoveries and theories, thus developing an awareness of the highest standards	A-C
15	Ethical awareness (relevant to physics)	be able to understand the socially related problems that confront the profession and to comprehend the ethical characteristics of research and of the professional activity in physics and its responsibility to protect public health and the environment	C
16	Foreign Language skills (relevant to physics)	Have improved command of foreign languages through participation in courses taught in foreign language: i.e. study abroad via exchange programmes, and recognition of credits at foreign universities or research centres	D
17	Specific Communication Skills	be able to work in an interdisciplinary team; be able to present one's own research or literature search results to professional as well as to lay audiences	D

[3] See previous footnote

- Second cycle

RATING OF IMPORTANCE ORDER	**SHORT NAME**[4] OF THE SUBJECT SPECIFIC COMPETENCE	**EXTENDED DESCRIPTION OF THE COMPETENCE** *on completion of a first cycle degree in Physics, the student should:*	**DUBLIN DESCRIPTOR LABEL**
1	Modelling & Problem solving skills	be able to identify the essentials of a process / situation and to set up a working model of the same; be able to perform the required approximations; i.e. critical thinking to construct physical models	B
2	Problem solving skills	be able to evaluate clearly the orders of magnitude in situations which are physically different, but show analogies, thus allowing the use of known solutions in new problems	B
3	Literature search	be able to search for and use physical and other technical literature, as well as any other sources of information relevant to research work and technical project development. Good knowledge of technical English is required.	E
4	Learning ability	be able to enter new fields through independent study	E
5	Modelling	Be able to adapt available models to new experimental data	B
6	Theoretical understanding	have a good understanding of the most important physical theories (logical and mathematical structure, experimental support, described physical phenomena)	A
7	Basic & Applied Research	Acquire an understanding of the nature and ways of physics research and of how physics research is applicable to many fields other than physics, e.g. engineering; be able to design experimental and/or theoretical procedures for: (i) solving current problems in academic or industrial research; (ii) improving the existing results	A-B-C
8	Deep knowledge	have a deep knowledge of the foundations of modern physics, say quantum theory, etc .	A
9	Mathematical skills	be able to understand and master the use of the most commonly used mathematical and numerical methods	A-B
10	Frontier research	Have a good knowledge of the state of the art in - at least - one of the presently active physics specialities	A
11	Problem solving and computer skills	be able to perform calculations independently, even when a small PC or a large computer is needed, including the development of software programmes	B
12	Experimental skill	have become familiar with most important experimental methods and be able to perform experiments independently, as well as to describe, analyse and critically evaluate experimental data	B
13	Specific Communication Skills	be able to work in an interdisciplinary team; be able to present one's own research or literature search results to professional as well as to lay audiences	D
14	Managing skills	be able to work with a high degree of autonomy, even accepting responsibilities in project planning and in the managing of structures	C
15	Human / professional skills	be able to develop a personal sense of responsibility, given the free choice of elective/optional courses; be able to gain professional flexibility through the wide spectrum of scientific techniques offered in the curriculum	A-B-C
16	Physics culture	Be familiar with the most important areas of physics and with those approaches, which span many areas in physics	A
17	Updating skills	Enjoy facility to remain informed of new developments and methods and be able to provide professional advice on their possible range of applications	E
18	Foreign Language skills (relevant to physics)	Have improved command of foreign languages through participation in courses taught in foreign language: i.e. study abroad via exchange programmes, and recognition of credits at foreign universities or research centres	D
19	Ethical awareness (relevant to physics)	be able to understand the socially related problems that confront the profession and to comprehend the ethical characteristics of research and of the professional activity in physics and its responsibility to protect public health and the environment	C
20	Absolute standards	have become familiar with "*the work of genius*", i.e. with the variety and delight of physical discoveries and theories, thus developing an awareness of the highest standards	A-B

[4] see footnote n.1

- Third cycle (subject specific and generic)

To be defined

3.3 Remarks about levels (or degree of competences development):

Many subject specific competences appear both in the 1st and 2nd cycle. However, their importance (i.e. rating order) is different. Each cycle is characterised by its own priorities. Indeed, most of the 7 best competences of the 1st cycle (i.e. except "*Problem Solving*" and "*Modelling and Problem Solving*") fall beyond the 8th position in the 2nd cycle ordering. In other words the skills which are most important in the first degree become somewhat less important in the 2nd cycle, probably because they are supposed to be satisfactorily developed already in the first cycle (see again for more details **pages 171-185 of Ref. [1]**).

For a given competence, the actual *average* rating value in the 1st cycle is always lower than in the 2nd cycle. Such lower values witness the fact that the competence development is a cumulative process. The rating *gap* across the two cycles can be taken as a "rough" measure of the further development, which has to be achieved in the 2nd cycle. Among the "Physics competences" the highest gaps are scored (in decreasing order) by[5] *Frontier research*, *Managing skills*, *Specific Communication Skills*, *Modelling*, *Updating skills*, *Learning ability*, *Literature search*. The lowest gaps are scored by *Absolute standards*, *Theoretical understanding*, *Physics culture*, *Mathematical skills*, *Problem solving* (minimum gap). The highest gaps identify competences, which are appropriate at 2nd cycle level, and small gaps identify competences, which should be already well developed in the 1st cycle.

Finally, our analysis shows that identification of a *common* core knowledge is certainly possible in Europe in the 1st cycle degree courses in Physics, but it becomes rather questionable in the 2nd cycle, essentially because each institution focus on a different specialisation (see Fig 2 at **page 197 of Ref [1]**). The common core knowledge of the 1st cycle is quite similar everywhere and shows a time-progression pattern, which is governed by the requirements needed to progress in the subject knowledge. Some variation occurs between the two main existing methodological approaches (i.e. synthetic and analytical approach).
In this general context, certain Physics sub-areas are visited and revisited again during the degree course(s), with the aim of achieving higher and higher levels of understanding.

3.4 Consultation process with stakeholders

The Tuning consultations among the Physics graduates (mostly in the pre-Bologna period) and their employers gave the following ranking of the generic competences (we list the first five competences only):

graduates	employers
Capacity for analysis and synthesis	Capacity for analysis and synthesis
Problem solving	Problem solving
Capacity to learn	Capacity to learn
applying knowledge in practice	applying knowledge in practice
Creativity	Teamwork

The results of the two consultations are strikingly similar. Compare with the Academics ranking (whose questionnaire however didn't include the generic skill "*problem solving*".

[5] only short names are given here

4. WORKLOAD AND ECTS

4.1 Workload of the typical degree programmes expressed in ECTS credits

- First cycle 180-240
- Second cycle 120[6]
- Third cycle usually three full years

In the case of the third cycle, ECTS might be used to describe the course work and/or to give the relative amount of the coursework with respect to the doctoral research activity. Indeed a normal enthusiast doctoral student in the area of Physics may work as much as 46 hours per week along 48 weeks (i.e. more than 2200 hours per year).

4.2 Trends and differences:

In the year 2002 the Tuning Network included two groups of institutions, almost equal in number (see **page 191 of Ref [1]**):

(i) Institutions with a "Bachelors – Masters (BaMa)" organisation of studies (i.e. a two-cycle organisation, mostly according to a "3+2" scheme). The institutions were: Kobenhavn, Granada, Nijmegen, Paris VI, Trieste, Dublin City University and Patras (which adopted a "4+2" scheme).

(ii) Institutions, which offer an Integrated Masters level degree course (i.e. a single cycle organisation, without an intermediate exit after 3 years). The institutions were: Gent, Göteborg, Chalmers University of Technology, Helsinki (Physics), Imperial College London, Aveiro, Hannover, Technical University Wien.

The *common core content* was practically the same in the two groups (see Fig 3 at **page 197 of Ref [1]**). Do notice that in the case of a two-cycle organisation of studies, the identification of a *common* core content is quite feasible in the 1st cycle, but it becomes questionable in the 2nd cycle (see above)

5. LEARNING, TEACHING AND ASSESSMENT

NB the complete Physics paper on the development of subject specific competences is given **elsewhere in this same book / site.**

Problem solving skills (first cycle)

Teaching / learning

Active Learning: in all classes (theory, lab or problem solving)

- *Several questions are posed to the theory class and a certain amount of time is allowed for discussion in the same class.*
- *Several question-problems are set to the class and assigned to groups of students. They should find an answer (either exact or approximate) in a certain amount of time. They are also requested to explain their reasoning to other students (Did they divide the problem in simpler problems? did they use analogies with problems, for which they already knew the answer? why are they confident about their own answer?…)*
- *In the exercise classes the students are requested to correct and comment other students ways of solving the exercises.*
- *In the lab classes students are frequently asked to solve experimentally or propose ways for solving other more complex problems that may be considered extensions of the material proposed in the class. (ex: after studying an LC circuit they are encouraged to solve the problem of coupled LC circuits and think about the problem of impedance adaptation in a transmission line).*

Problem solving and computer skills (first cycle)

Teaching / learning

…each of the four compulsory course units in theoretical physics, i.e., classical physics with mechanics, electrodynamics and relativity, quantum mechanics, statistical mechanics and advanced quantum mechanics with an introduction to quantum field theory, are supplemented by a computer project of ½ semester length ".

[6] there are exceptions, e.g. Imperial College in London,

Moreover, the research training during the final master thesis work, *is usually also computer-based and therefore requires and trains computational skills in varying aspects depending on the research field, being it in theoretical, experimental or applied physics.*

Modelling (second cycle)

Teaching / learning

Modelling in a narrow sense means finding a simplified mathematical description of a complex phenomenon. It often means also applying tools of theoretical physics to non-physics situations.

… There is no course unit named Modelling. Students learn the modelling description of nature throughout their whole degree-course. Possible examples are: the "modelling" neglect of friction in the description of the free fall, the abundant use of harmonic oscillator for phenomena in the neighbourhood of stable equilibria*, the shell model average field for nucleons in nuclei, the modelling of two-nucleon and three-nucleon forces, and so on.*

The whole teaching offer is then important: in lectures, exercise classes, in lab classes, in student seminars and during research training students learn about how theories were developed, how to select and then apply theoretical tools (e.g. models) to a particular physical problem and how to model the building blocks of a theory, by adapting these latter to the experimental data description.

Learning ability (second cycle)

Teaching / learning

The students and the teachers "*are unanimous in stating that the major relevant strategy is to include in the teaching methods small individual and team project-works (either theoretical or experimental ones)".* More particularly, "*since our degree-course is an applied one, most of the project works include an experiment: the students are asked to measure some quantity. Before doing the experiment itself, they have to plan it (experimentally and theoretically) and explain their choices (why are they using a given experimental method, which temperature intervals will they be covering, do they have everything in the lab or do they have to build some equipment or circuit in the workshop,…). The students then go to the lab and measure whatever is necessary. Afterwards they need to learn some new physics in order to interpret the data. In the last two years some units give a weight as much as 50% and more to this type of work".*

Theoretical understanding (first cycle)

Assessment

Oral comprehensive exams are used to assess quite effectively the degree to which students have overcome difficulties in understanding and in using the understanding. Those exams are taken by the end of the 4th semester in the subjects experimental physics, theoretical physics, mathematics and in an elective subject [and in the final oral MSc exam in experimental physics, theoretical physics and in two elective subjects].

Literature search (first and second cycle)

Teaching / Learning/Assessment

A seminar-based unit is taken by all students in years 1 and 2. It includes exercises in finding sources and in summarizing information from them. This is supported by discussions with staff and with particular instruction in use of library and internet facilities. They also are required to give presentations in Year 1 on topics resulting from literature surveys. They also will do a project in Year 1, which will include a literature survey.

The final research project (master level) will typically start with a guided literature search of a particular topic. The results of this must be reported by the student. Guidance on this is also given, in a special unit.

The students must fully engage in the above activities and present their results to the seminar leader, their tutor or their research supervisor. Performance in written summaries and oral presentations in Years 1 and 2 are assessed and given a mark. Competence in this area as part of both the 1st year project and the final research project is assessed as a specific part of the students' project assessment. The summaries of papers are marked too.

6. QUALITY ENHANCEMENT

No specific physics recommendation was produced as such. The Tuning network in Physics recognises itself in the general Tuning paper about Quality enhancement. One member of the

Physics Group gave an important contribution to it. In very general terms we add here that – during the Physics SAG works – it was often stressed the importance of the educational context for the quality of the Physics degree programme, i.e. the importance of the general academic atmosphere / resources of a university and of its research environment.

References

[1] "*Tuning Educational Structures in Europe, Final Report, Pilot Project – Phase 1*, carried out by over 100 Universities, co-ordinated by the University of Deusto (Spain) and the University of Groningen (The Netherlands) and supported by the European Commission", edited by Julia Gonzalez and Robert Wagenaar, University of Deusto and University of Groningen, 2003.

[2] See the *Report of Working Group 1: The student experience (The questionnaire on the doctoral studies)*, pages 13 - 43 in "Inquiries into European Higher Education in Physics", Proceedings of the third EUPEN General Forum 99, London (GB), September 1999, edited by H. Ferdinande & A. Petit , Volume 3, Universiteit Gent, Gent 1999

ANNEX I

RELATION BETWEEN THE PHYSICS SUBJECT SPECIFIC COMPETENCES AND THE DUBLIN DESCRIPTORS (DDs)

Premise

The DDs vary and upgrade when passing from the first to the second cycle. The Tuning Physics Descriptors are the Physics subject specific competences. Their importance in each cycle was identified via a "rating procedure", carried out by several Physics academics. The rating was carried out for both 1st and 2nd cycle on each competence belonging to a list of 24 competences, which had been prepared by the Physics SAG, in co-operation with the Physics Socrates Thematic Network, named *EUPEN-EUropean Physics Education Network*. The rating produced two ordered lists of competences, one per cycle; the order identifies the priority scale or the importance of the involved competences in each cycle. For more details see **pages 171-185 of Ref. [1]**.

Physics competences versus DDs

We carried out the exercise of assigning each Physics competence to the appropriate "dimension(s)" of the DDs. It turns out that all competences can be *assigned to* or *labelled by* at least one among the DD dimensions, as shown in the Tables given above under the heading LEARNING OUTCOMES AND COMPETENCES – LEVEL CYCLE DESCRIPTORS. The distribution of the Physics subject specific competences over the five dimensions of the DDs is shown in the table below (we considered the distribution of the first 17 competences in each cycle; moreover, when a competence covers more DDs, it is assigned once to each of them).

Table I - Distribution over the DDs of the first 17 Physics competences in the first and in the second cycle

Dublin Descriptor label	Dublin Descriptor dimension	No. of Physics specific competences per Dublin Descriptor dimension	
		First cycle	Second cycle
A	Knowledge and understanding	7	7
B	Applying knowledge and understanding	8	8
C	Making judgements	3	3
D	Communications skills	2	1
E	Learning skills	2	3

The distributions among the DDs involve almost the same competences in both cycles. The main remarks here are:

- all Physics competences can fit very well the DDs;
- the Physics competences mostly populate the DDs, which are labelled A or B (as to be expected);

- as to the competences counted under C, they are essentially limited to scientific judgements ;
- a very limited number of competences covers two or even three different DDs (multiple fit).

Even though the above distributions over the DDs involve almost the same competences in both cycles, their rating order – however – is quite different in the two cycles, i.e. their priority/importance is felt as different by the Physics academics. It is then instructive to look at the sequence of the DDs labels, which in each cycle is generated by the ordered sequence of Physics competences. The two sequences are:

First cycle: **B, A, A-B, A, B-C, B, B, A, A-B, A-B-C, ….**

Second cycle **B, B, E, E, B, A, A-B-C, A, A-B, A, …..**

We may very well say that the two sequences identify which general DDs are more relevant in each of the two Physics cycles. If we limit ourselves to the first – say – seven competences, we see that:

- the first cycle is characterised by preferred competences, which mostly fall under the labels A and B;
- the second cycle is characterised by preferred competences, which fall under the labels B and E (!). It is worthwhile noticing that in the second cycle the dimension *learning to learn* is considered to be outstandingly important.

Moreover and in more detail, if we now go back to the tables, which in the main text list the Physics specific competences, and look at the competences of the first cycle, which are labelled as A, we see that they move quite back in the rated order of importance, when passing from the first to the second cycle: indeed they are quite "general" competences, which may be supposed – so to speak – as satisfactorily developed already in the first cycle. Viceversa, several competences, which are less important or less developed in the first cycle and which are labelled as B and E, move on in the second cycle.

As a conclusion, in the present context the cycle levels are well described by the sequences of the first – say – seven competences and by their distribution over the DDs. The order describes the relative importance of the competence in the given cycle, the distribution over the DDs gives an idea of the relative weight of the 5 dimensions of the DDs in each cycle (see Table II here below).

Table II - Distribution over the DDs of the first 7 Physics competences in the first and in the second cycle

Dublin Descriptor label	Dublin Descriptor dimension	No. of Physics specific competences per Dublin Descriptor dimension	
		First cycle	Second cycle
A	Knowledge and understanding	5	2
B	Applying knowledge and understanding	5	4
C	Making judgements	1	1
D	Communications skills	0	0
E	Learning skills	0	2

From Table II the main differences between the first an the second cycle are:

- the first cycle shows a balanced attention to both *Knowledge and understanding* and *Applying knowledge and understanding*; but the attention to *Knowledge and understanding* is rather higher than in the second cycle;
- the second cycle, which of course is still focused on *Knowledge and understanding*, nevertheless clearly privileges *Applying knowledge and understanding* and puts in the forefront the dimension *Learning skills*, this latter dimension enjoying a definitely lower preference in the first cycle.