The subject of Physics from an international perspective

Physics A and B in HTX and STX

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Contents

1 Summary

This report presents the results of the evaluation from an international perspective of Physics at levels A and B in the upper secondary education programmes HTX (higher technical examination) and STX (the general upper secondary programme) in Denmark. The evaluation was commissioned by the Danish Ministry of Education and can be regarded as a supplement to the national evaluation of Physics carried out by EVA at the request of the Danish Ministry of Education. Mathematics has also been evaluated from an international perspective, and a parallel report presents the results of that evaluation.

Purpose and organisation of the evaluation
In August 2005, a sweeping reform of upper secondary education took effect in Denmark. The reform has entailed structural changes to upper secondary education programmes as well as alterations to the individual subjects taught in the programmes. On the basis of a comparison of the Physics curricula and examination sets before and after the reform this evaluation aims to assess the relevance of the development of Physics from an international perspective.

An international expert panel has discussed and assessed the development of Physics in relation to international developments and trends within Physics in upper secondary education, and requirements regarding Physics in further education. The composition of the expert panel covers different areas of expertise within the field of Physics and Physics education. The expert panel is responsible for the conclusions in the evaluation, while EVA has been responsible for the organisation of the evaluation and writing of the report.

Various dimensions of Physics
The subject of Physics has different profiles in the HTX and the STX programmes. In HTX, the subject is mainly characterised by a technological and practical focus, whereas the subject in STX has a broader and more classical approach. However, in both programmes the subject is centred on the interaction between theory and experiments, which has not been changed by the reform. Generally, the new curricula could be seen as a continuation and reinforcement of a development of Physics in the programmes that has been going on over an extended period of time.

The new curricula in both programmes emphasise that Physics should appear relevant and attractive to pupils, for instance by including realistic themes from research, commerce and everyday life. This corresponds, according to the expert panel, to trends seen in other European countries, including increased emphasis on conceptual Physics rather than the mathematical aspects of Physics. The expert panel finds the enhanced focus on pupils´ positive views of Physics highly relevant, and the conceptual Physics approach valuable for teaching and motivating. However, the panel emphasises that conceptual Physics cannot stand alone, but should be supplemented by theoretical and mathematical physical knowledge.

The new curricula entail new possibilities and requirements regarding interdisciplinary work in both programmes. Furthermore, the requirement for using IT in the subject has been strengthened. Generally, the expert panel considers that these approaches to the subject reflect a modernisation of the subject, which corresponds to general developments in the field of Physics within research, companies and universities. However, the panel emphasises that it is important to balance modernisation with the traditional theoretical parts of the subject. It is, for example, important to develop pupils' fundamental skills within pure Physics in order for them to be able to take part in interdisciplinary projects in a scientific education or career.

Competence aims and content description

Overall, the new curricula place more emphasis on describing the subject aims in terms of the competences that pupils are to achieve than did the former. At the same time, the level of freedom permitted to the local teacher group to choose which content is most appropriate in order to achieve these aims is enhanced. Thus, the level of detail in defining the content is reduced, and the content is divided into core material and extension material, which intends to enable interdisciplinary projects. According to the expert panel, the enhanced focus on competences is in line with the development within the subject of Physics in many other European countries. The expert panel underlines that competence is a useful concept in the curricula as it describes how the pupils are able to use their knowledge of the subject. At the same time, the expert panel finds it important that competences are complemented by content descriptions in order to clarify the specific level of the teaching. Furthermore, the expert panel welcomes the motivation and flexibility created by the extension material but thinks that it could be questioned whether the extension material makes up too large a proportion compared to the core material.

Both knowledge *in* Physics and knowledge *about* Physics is important

Generally, the expert panel assesses that the subject aims in both of the programmes are relevant and comprehensive. According to the expert panel it is, however, crucial that pupils acquire knowledge of the core of the subject – knowledge *in* Physics – as a foundation for developing broader competences as well. This includes knowledge of the core content areas including fundamental laws and concepts, and competences that build on mathematical skills, e.g. calculating skills and modelling. On the other hand, the panel finds it important to support the development of broader competences related to the general education aspect, including: an understanding of scientific methodology in a wider perspective; communication skills; the ability to put Physics in a larger perspective and to understand its contribution to the worldview; and finally, competences that involve discussing and assessing physical findings. Internationally, these broader and more generic aspects – knowledge *about* Physics and science – are gaining increased focus in Physics education. The expert panel finds it important to find an adequate balance between the core Physics competences and the broader more generic competences. It is not about choosing one competence over the other, but about finding a good balance.

Important to balance classical and modern content

Overall, the expert panel considers the content of Physics defined by the core material to be relevant in both of the programmes and to correspond adequately to the subject at upper secondary level in other European countries. The expert panel welcomes the innovations and modernisation regarding the new topics in the STX programme. The new topics seem appropriate in order to create motivation. However, the expert panel finds it important to strike an appropriate balance between classical and modern Physics, and emphasises that solid knowledge within classical Physics is crucial. In this context the expert panel regrets that electromagnetism has been left out of the STX programme at level A in spite of its basic and technological importance.

Oral and written examinations compare well internationally

The expert panel approves of the oral examinations which include an experimental part. The oral examinations enable the evaluation of some of the more generic competences regarding the nature of science. The expert panel furthermore emphasises the practical element of Physics in the teaching and thus finds it valuable to integrate the evaluation of the pupils' work with experiments in the examination. The expert panel assesses that the level in the written test sets in both programmes compares well internationally. However, the expert panel assesses that the HTX test set from 2008 might have been too ambitious. Comparing the test sets before and after the reform, the expert panel finds that the new test sets are more innovative. They are especially developed with regard to the use of IT, the demand that pupils make their own assumptions and the increased use of context descriptions. These developments correspond well to the competences emphasised in the curricula and the profiles of Physics within the respective programmes. However, the panel notes that the amount of text in the questions is larger which can be an obstacle for poor readers.

2 Introduction

This report presents the results of the evaluation of Physics in the upper secondary education programmes HTX and STX from an international perspective. It discusses and analyses Physics at levels A and B with regard to the development of the subject and can be regarded as a supplement to the national evaluation of Physics. This international evaluation was commissioned by the Danish Ministry of Education and was conducted by the Danish Evaluation Institute (EVA) in co-operation with an international panel of experts within the fields of Physics and Physics education.

2.1 Background to the evaluation

In August 2005, a sweeping reform of Upper Secondary Education took effect. The reform intends to strengthen and renew the quality of the education programmes according to the needs and requirements entailed by societal changes. The reform has entailed major structural changes to the upper secondary educational programmes as well as alterations to the individual subjects taught in the programmes.

At the request of the Danish Ministry of Education's Department of General Upper Secondary Education, the Danish Evaluation Institute (EVA) has during 2008 carried out a number of evaluations of subjects taught in upper secondary education programmes, including evaluations of Physics and Mathematics. These evaluations have been completed according to a specified procedure adopted by EVA in all subject evaluations conducted in connection with the Danish reform of upper secondary education. The procedure requires that the subjects are evaluated according to existing guidelines, i.e. ministerial orders, curricula and guidelines issued in connection with the reform. The subject evaluations focus partly on the teachers' experiences of the new guidelines, and partly on the outcome of the teaching. Thus, they illustrate the extent to which the aims in the curricula are achieved and how the pupils benefit from the organisation of the teaching.

In addition to the national evaluations of a number of subjects in the upper secondary programmes, the Department of General Upper Secondary Education has commissioned EVA to carry out supplementary evaluations of Physics at levels A and B, and Mathematics at levels A and B in HTX (higher technical examination programme) and STX (the Danish *Gymnasium* – general upper secondary programme) from an international perspective. This report presents the evaluation of the subject of Physics from an international perspective. There is a parallel report presenting the international evaluation of Mathematics.

2.2 Purpose and setting of the evaluation

The purpose of this evaluation is to supplement the national subject evaluations with an international perspective on the development within the subject of Physics. The relevance of the development in the subject is assessed in terms of general education and the pupils' preparedness for higher education by an independent panel of international experts. The evaluation deals with Physics at levels A and B in HTX and STX, thus narrowing the focus from other programmes and levels. The programmes and levels are described in section 3.1.

On the basis of a comparison of the curricula and written test sets before and after the reform the evaluation assesses the relevance of the development in Physics from an international perspective. The analysis of the development in the subject covers the following issues:

- Standing of Physics in the programmes;
- Subject aims;
- Subject content;
- Principles of pedagogic organisation, including the requirements of interdisciplinary interaction;
- The form and content of the examinations.

The setting of the evaluation involves certain possibilities and limitations that are decisive for the results presented in this report. In this connection, it is important to stress the main premises for the evaluation-process.

This evaluation focuses on the overall framework for and new approaches to the subject of Physics at a central level, rather than the actual local implementation. The core issue is the official framework for the subject of Physics as set up by the Ministry of Education, i.e. the formal curricula and selected national examination sets. The local implementation of the changes is undoubtedly decisive for the development of the subject of Physics, and thus it is difficult to totally isolate the discussions and assessments in the evaluation from the implications connected with the implementation. However, it is important to note that this evaluation does not include documentation of local implementation.

The reform of 2005 is still in the process of being implemented in the general upper secondary education programmes, and only one year group of pupils have completed the programmes according to the reform. Thus, this international subject evaluation – as well as the national one – has been carried out while the reform is still relatively young, and it is of course too early to assess how the reform has influenced pupils' success in higher education, which should be kept in mind by readers of the report. Thus, the discussions in this report concentrate on the potentials of the new approaches to the subject.

In this evaluation the development of Physics as a subject is evaluated *from an international perspective*. Here, this implies that an expert panel consisting of foreign and internationally oriented experts has discussed and assessed developments in the subject as identified by the sources of documentation in relation to international developments and trends within the field. However, an exhaustive mapping of international tendencies has not been carried out. The expert panel's composition covers different areas of expertise within the field of Physics and Physics education. Thus, the analyses and reflections in this report are based on the professional experience and knowledge of the individual members of the expert panel.

2.3 Project organisation

The expert panel comprises three international experts, and the panel is composed to ensure that the following areas of expertise and knowledge are covered:

- Academic expertise;
- Knowledge about Physics at the "user" level, for instance in the higher education system;
- Knowledge about the standing of Physics in the international educational arena;
- Knowledge about international trends within Physics in higher education.

The members of the expert panel are:

- Carl Angell, Associate Professor, University of Oslo, Physics Education Group, Department of Physics;
- Brian Bech Nielsen, Professor, University of Aarhus, Department of Physics and Astronomy and Interdisciplinary Nanoscience Center (iNANO);
- Hendrik Ferdinande, Retired Senior Lecturer, Ghent University, Chair of the European Physics Education Network (EUPEN).

More detailed information on the expert panel is provided in appendix A.

The expert panel is responsible for the conclusions of the evaluation. The task of the expert panel has been to carry out the subject-related analysis and to evaluate the subject of Physics from an international perspective, while EVA has been responsible for the organisation of the evaluation, the methodological aspects and the writing of the report. The expert panel has attended two one-day meetings at EVA during December 2008 and January 2009, which included discussions of the written documentation and interviews with key persons.

The project team at EVA comprises: Evaluation Officer Katrine Strange and Evaluation Assistant Louise Bunnage. In addition, Evaluation Officer Henriette Pedersen and Evaluation Officer Bo Söderberg have participated in selected parts of the evaluation. Evaluation Officer Rikke Sørup is the project manager of the Subject Evaluations 2008.

2.4 Sources of documentation

The main sources of documentation include former and present curricula and test sets that have all been translated into English. The translation of the documents is provided by the Danish Ministry of Education. In addition, the evaluation includes interviews with key persons within the field and other sources of documentation. These sources are described below.

Former and present curricula

The main reference for the analysis of the development in the subject of Physics in this evaluation has been the Physics curricula imposed by the Danish Ministry of Education. The curricula are formal documents which all schools and teachers are committed to comply with. In this way, the curricula form the central framework of the subject. By scrutinising and comparing the former and present curricula, the aim has been to identify the development of the guidelines and framework for the subject, and to assess the development from an international perspective.

The curricula are relatively brief documents, and the Ministry of Education has formulated more detailed teaching guidelines that go into greater depth concerning the different aspects of the curricula, explaining and giving examples of how to implement the elements. These guidelines are, however, not compulsory. The guidelines in their entirety do not form part of the documentation material for this evaluation. However, the section in the guidelines regarding assessment criteria has been used as background information (See descriptions of other sources of documentation below).

The following curricula have been used in the evaluation:

- Present curricula:
  - Physics A and B in HTX (executive order 743 of 30.06.2008, appendices 13 and 14)
  - Physics A and B in STX (executive order 741 of 30.06.2008, appendices 23 and 24)
- Former curricula:
  - Physics A and B in HTX (executive order 524 of 15.06.2000, appendix 9)
  - Physics A and B in STX (executive order 820 of 04.11.1999, appendix 14)
  - Physics A and B in STX (executive order 319 of 19.05.1993, appendix 13)

Test sets used in written examinations

Another main source of documentation which reflects the development in the subject of Physics is the test sets used in the written examinations[1]. The test sets show among other things which competences and skills are tested when the pupils complete the course. The test sets also to some extent reflect the competences and skills that are in focus in the teaching, insofar as the teaching is affected by and dependent on the examination. There is a tradition of using previous years' test sets[2] in the teaching and as assignments to prepare the pupils for the kind of questions they can expect in the examination.

[1] *There is only a written examination at level A.*

[2] *In connection with the reform, guiding test sets have been prepared especially to comply with this tradition.*

The test sets provide an opportunity to analyse and understand the development in the subject with regard to the level of difficulty, the content and the types of competences and skills that are in focus in the subject. Combined with the exam results the test sets to some extent indicate which competences and skills pupils are expected to possess when leaving the education programme.

The following post-reform test sets are included:
- Written exam at A-level in HTX, summer of 2008;
- Written exam at A-level in STX, summer of 2008.

The following test sets prior to the reform are included:
- Written exam at A-level in HTX, summer of 2007[3];
- Written exam at A- level in STX, summer of 2000[4];
- Written exam at A- level in STX, summer of 1991.

Interviews with key persons

With the aim of complementing the official written documents, the expert panel has carried out a number of interviews with key persons having knowledge of the intentions and ambitions behind the reform of the subject as well as the practical importance of the changes. Thus, the interviews served to clarify uncertainties when reading the documents and have, furthermore, contributed towards a deeper understanding of the development in the subject.

The key persons interviewed by the panel were:
- *The subject advisors for Physics*. Each programme has a subject advisor who is employed – often part time – by the Ministry of Education. Subject advisors have overall responsibility for the subject and take part among other things in preparing and updating curricula. Besides their work as subject advisors, they are often part time teachers. They play a key role as the link between the ministry on the one side, which is in charge of the official guidelines for the subject, and the school and teachers on the other, which constitute the implementation level.
- *Representatives of the exam commissions*. For both HTX and STX, there are central exam commissions that compose the national written test sets. The exam commissions are appointed by the Ministry of Education and comprise a number of highly experienced Physics teachers, and sometimes representative from a university.
- *Chair of the Physics association in STX.* The Physics teachers in the STX programme are organised in a subject association that collaborates with the Ministry of Education. The association serves as a forum for teachers to share material, experiences and knowledge. There is at present no association representing the HTX Physics teachers.

More detailed information on the persons interviewed is provided in appendix B.

Other sources of documentation

The following sources of documentation have served as background information for the expert panel's assessments:
- Statistical data regarding grades and the standing of Physics in the upper secondary programmes, including data on the proportion of pupils at A and B levels;
- Assessment criteria, including examples of when to give the grades 02, 7 and 12 (extracts from the official guidelines);
- Survey data from EVA's national evaluations of Physics concerning the knowledge, skills and competences acquired by the pupils. A questionnaire survey among Danish Physics teachers and examiners, carried out in 2008.

[3] The last pupils that completed the program "before the reform" commenced in 2004 and completed the programme in the summer of 2007.

[4] The selected STX test sets prior to the reform follow the years where the subject curricula have previously been revised.

2.5 Content of the report

The report contains an executive summary, this introductory chapter, four main chapters and six appendices.

The executive summary in chapter one presents the main conclusions of the evaluation in terms of the expert panel's reflections and assessments regarding developments in the subject of Physics. Chapter 2 introduces the background and purpose of the evaluation as well as the relevant methodological aspects of the evaluation.

Chapter 3 presents the structural placement of the subject of Physics in the educational context, including a short introduction to the Danish upper secondary education system, particularly the STX and HTX programmes, the 2005 reform and the post-reform standing of Physics in the two programmes.

Chapters 4 – 6 present the development in the subject identified by comparing the former and the present curricula and test sets, and the expert panel's reflections and assessment of these developments. Chapter 4 focuses on the overall approaches to the subject and the teaching of Physics. Chapters 5 and 6 go into further detail concerning, respectively, the subject aims and content, and the examinations.

3 Danish upper secondary education and Physics

This chapter presents the structural placement of the subject of Physics in the two upper secondary programmes. Firstly, the chapter places the HTX and STX programmes in relation to the Danish system of upper secondary education, looking into the purpose, focus and scope of the two programmes. Secondly, the chapter gives an account of the main changes brought in by the 2005 reform of upper secondary education in Denmark. Finally, the chapter outlines the standing of Physics in the HTX and STX programmes after the reform, including an account of the respective formal levels of the subject in the programmes and the development of pupils' choices of levels.

3.1 Education programmes at upper secondary level

Four different upper secondary education programmes[5] exist in Denmark: the general upper secondary education programme (STX); the higher commercial examination (HHX); the higher technical examination (HTX); and the higher preparatory examination (HF). STX, HHX and HTX take three years to complete and admit pupils that have completed nine years of primary and lower secondary school. When enrolled in these programmes, pupils are approximately 15-17 years old. HF takes two years to complete and admits pupils that have completed 10 years of basic school. These pupils are often older than 16 when they enrol in the programme. Over 50% of a Danish year group completes an upper secondary education programme.

The STX and HF programmes are general and cover a broad range of subjects in the fields of humanities, natural and social sciences. The HHX and HTX programmes have a more vocational focus: HHX focuses on business and socio-economic disciplines in combination with foreign languages and other general subjects; HTX emphasises technological and scientific subjects in combination with general subjects.

Each of the education programmes has its specific range of compulsory subjects. Additionally, in STX, HHX and HTX, each school offers a number of different specialised study packages (normally containing three subjects) and elective subjects for the pupils to choose from. All subjects are placed in system of levels, C, B and A, in relation to the subject's scope and depth, A being the highest level. C-level subjects are, normally, allotted 75 lessons of 60 minutes, B-level subjects have, normally, 200 lessons, and subjects at A-level have, normally, 325 lessons. There are, however, a number of exceptions in the individual programmes, in particular regarding B and A-levels.

This evaluation focuses on Physics in STX and HTX. Both programmes aim at preparing pupils for higher education and providing general education (*almen dannelse* in Danish) – as do HHX and HF. The two programmes are, however, based on different traditions and have different areas of focus.

In STX, the pupils are to be generally educated and to obtain study skills within the humanities, natural science and social science, which will enable them to enrol in and complete a programme of higher education. Traditional classical subjects have had a central role in the programme. STX reflects a tradition of several hundred years, with roots back to the Middle Ages. The HTX programme on the other hand, is a relatively new programme, established in 1982. The objective for

[5] In OECD terms, Danish Upper Secondary Education corresponds to ISCED level 3.

the establishment of HTX was a desire to offer a broader range of education and training possibilities and a desire to create a new and relevant way to access Higher Education within technical areas. Therefore the emphasis in the HTX programme is on technological perspectives. The aim of preparing pupils for academic studies is realised within the areas of technological development, natural science and other general subjects. Furthermore, HTX has a tradition of interdisciplinary teaching and of using projects and topic based tasks in the teaching.

The table below provides an overview of the similarities and differences between HTX and STX.

Table 1
HTX and STX

	HTX	STX
General aim	To provide general education and to prepare the pupils for higher education.	
Focus	• Emphasis on vocational perspectives; • The preparation for further study is oriented towards areas of technology and scientific subjects in combination with general subjects; • The pupils should be able to study in depth and analyse practical issues.	• Emphasis on general education: • The preparation for further study is general, but the academic standard is closely linked to aspects of the academic subjects; • The pupils should achieve general education and study competences within the humanities, natural science and social science.
Scope	• Approximately 2,500 pupils completed the HTX programme in the summer of 2008, which corresponds to 8% of the pupils that completed an upper secondary education in 2008.	• Approximately 19,800 pupils completed the STX programme in the summer of 2008, which corresponds to 59% of the pupils that completed an upper secondary education in 2008.

3.2 The reform of upper secondary education

In 2003, a political agreement was made to reform upper secondary education, and the reform was put into effect in 2005. The overall aim of the reform is to strengthen and renew the quality of the upper secondary education according to needs and requirements brought about by changes in society. It intended to make significant changes in the upper secondary education programmes and serves three overall goals:
- To strengthen the pupils' preparedness for higher education;
- To update and extend the general education function;
- To create a clear profile for each upper secondary education programme and, at the same time, enhance the equivalence between them and establish similar structures to the programmes.

The reform includes changes to the structure of the programmes as a whole, as well as new curricula and aims at subject level. A central aspect in the new curricula is a transformation from a focus on content listed in a syllabus to a focus on aims and competences. This implies an enhanced focus on the pupils' ability to apply their achieved skills in different contexts. Furthermore, the new curricula regulate pedagogic approaches and interaction between the subjects, and introduce new examination types.

A major structural innovation in the reform is the introduction of an introductory period of one semester for all pupils enrolled in a general upper secondary education programme. The purpose of this introductory period is to give the pupils an opportunity to learn more about the different subjects in order to make a qualified choice of which subjects they wish to focus on in particular. At the end of the introductory period, each pupil chooses a specialised study programme consisting of a package of, normally, three subjects. This is a significant change from the previous structure which consisted only of compulsory and elective subjects. Prior to the reform the pupils could choose from a range of electives, thus assembling an individual composition of subjects (within certain limits of combinations). Following the reform, the pupils have a limited choice between predefined subject-packages provided by the schools. These packages are central to the individual programme, which also contains compulsory subjects and a few electives.

The reform emphasises interaction between different subjects. Firstly, there is to be a close interaction between the subjects within the specialised study programmes. Secondly, interdisciplinary courses have been introduced called *general study preparation* in STX (Almen studieforberedelse in Danish) or *the study programme* in HTX (Studieområdet in Danish). These courses consist only of interdisciplinary projects and focus on general education and preparation for higher education.

The new curricula contain less compulsory material than previously. Thus, the freedom for teachers to choose content has increased; although the subject aims need to be achieved. This flexibility is intended to make it possible to facilitate work with topics that are suitable for interdisciplinary projects, and at the same time to leave more time for going into depth with a particular topic of special interest to the individual class or pupil.

An intention of the reform was to prioritise the natural sciences, Mathematics and technological development. Therefore, more pupils are required to study subjects within the natural sciences and should have the possibility to go into greater depth with these. Moreover, it has been intended to strengthen the natural sciences' contribution to the aim of general education and preparation for further study in the programmes. The natural science subjects thus have to form part of the interdisciplinary coursework of *the study programme* (HTX) and *general study preparation* (STX).

In HTX, the strengthening of natural science has been less significant than in STX, as the scientific subjects already had a high priority in the HTX programme. Thus, both Mathematics and Physics at level B are compulsory in the HTX programme. Nonetheless, the scientific and the technological subjects have gained more equal priorities with regard to forming the core of the education programme.

In STX the intention of strengthening the natural science subjects means that:

- Mathematics and Physics as distinct subjects at level C is now compulsory for all pupils. In addition, all pupils have to study at least two of the other subjects within the natural sciences (Chemistry, Biology or Natural Geography). At least one of the scientific subjects, (Physics, Chemistry, Biology or natural Geography) must, furthermore, be studied at a minimum of level B, while the other can be studied at level C.
- New possibilities and requirements exist for interaction between scientific subjects. 60 hours are allotted for a natural science basic course within the first semester of introduction. The purpose of this course is to give the pupils a grasp of the scientific methodologies, i.e. both the differences and the similarities between the respective subjects within the natural sciences.

3.3 The post-reform standing of the subject of Physics

In HTX, Physics is taught at two levels: A and B; A being the highest level. Level B is compulsory and consists of 190 teaching lessons of 60 minutes. A number of the specialised study programmes include Physics A which consists of 315 teaching lessons. Pupils who, after having studied Physics at level B, want to continue to level A can do so by adding 125 teaching lessons.

In STX, Physics is taught at three levels: A, B and C. Level C is compulsory and consists of 75 teaching lessons. However, the pupils can also at the outset choose to study Physics at level B or A. Level B consists of 200 teaching lessons in total, whereas level A consists of 325 teaching lessons in total. Alternatively, pupils starting at level C have the option of continuing to level B or A, and the pupils starting at level B have the option of continuing to level A; by adding 125 teaching lessons for each level.

There is a progression from level B to A. In HTX, for example, level B deals with "giving an account of physical, technical and technological problems…", whereas level A deals with "analysing and assessing physical, technical and technological problems…". Another example of progression can be found in STX, where level B deals with "calculations of physical quantities based upon basic concepts and models. Level A deals with "analysing a problem using different representations of the data, and formulating a solution for the problem using a suitable model". Thus, level A involves a higher degree of abstraction and an extended content area.

Pupils' choices of levels

The choices of levels are relevant for pupils that continue to higher education programmes after completing the upper secondary education programme. Physics at a minimum of level B is required by all major Danish Universities in order to study one of the natural sciences (Biology, Biochemistry, Chemistry, Geology and Physics), medicine and a substantial number of engineering subjects. In addition, all these higher education programmes require Mathematics at level A and chemistry at least at level B.

The reform of 2005 has brought along structural changes in the upper secondary education programmes, e.g. the introduction of specialised study-packages. These changes have, along with other factors, affected the standing of Physics in HTX and STX in different ways.

In 2008, almost 30% of all pupils that completed an upper secondary education programme in Denmark had Physics at level A or B – 9% had level A and 21% had level B. In 2005, it was almost 40%. The total decrease in pupils studying Physics is caused by a decrease in the number of pupils studying Physics at level B in STX, whereas the number of pupils studying Physics at level A has increased in total. The development within the two programmes is elaborated below.

Physics in HTX

Physics A is the third most chosen non-compulsory subject among pupils that will complete the HTX programme in 2009. 37% of pupils have chosen Physics at level A, either as part of a special programme or as an elective subject. The table below shows the tendency for pupils with Physics levels A and B in HTX for the period 2005-2009.

Table 2

Share of pupils leaving the HTX programme with Physics at levels A and B

Subject and level	2005-07	2008	2009
Physics A	22%	34%	37%
Physics B	78%	66%	63%
Total	100%	100%	100%

Source: UNI C Statistics and Analysis

Note: For the years 2005-2007, the average for the three years is shown. Number of pupils in total (N) (2005) = 2,115, N (2006) = 2,227, N (2007) = 2,228, N (2008) = 2,403, N (2009) = 2,616 (The number of pupils that are expected to complete the HTX programme in the summer of 2009.)

The table illustrates a significant increase in the proportion of pupils choosing Physics at level A, from 22% in the years 2005-2007 to 37% in 2009.

Table 3

Subject combinations – HTX

Combination	2006-07	2009	Change (percentage points)
Mathematics A + Physics A + Chemistry A	<1%	7%	+ 7
Mathematics A + Physics and Chemistry – one at A level, the other at least at B level	25%	47%	+22
Mathematics A + Physics and Chemistry – both at least at level B	45%	79%	+34

Source: UNI C Statistics and Analysis

Note: For the years 2006-2007, the average for the two years is shown. Number of pupils in total (N) (2006) = 2,227, N (2007) = 2,228, N (2009) = 2,616 (The number of pupils that are expected to complete the HTX programme in the summer of 2009.)

According to the statistical material regarding pupils' choices of subject packages, there is an increase in the number of pupils choosing the combination of Mathematics A and both Physics and Chemistry at least at level B, from 45% in 2006-2007 to 79% in 2009. Furthermore, the combination of Mathematics, Physics and chemistry, all at level A, has changed from being almost non-existent to being a combination chosen by 7% of the pupils for 2009. For higher education programmes within Physics and Chemistry, which normally require Mathematics at A level and either Physics or Chemistry at A level and the other at least at B level, the proportion of pupils with the necessary combination has also increased substantially, from 25% to 47%. Thus, Physics and the required combination to continue with university studies in natural sciences, medicine or several engineering subjects have been strengthened, in line with the ambition of the reform.

Physics in STX

The reform brought along structural changes to Physics in STX. On the one hand, Physics C has become a compulsory subject. On the other hand, Physics B forms part of only some of the study packages offered to the pupils. The table below shows the tendency for pupils studying Physics at levels A, B and C in STX for the period 2005-2009.

Table 4

Share of pupils leaving the STX programme with Physics at levels A, B and C

Subject and level	2005-07	2008	2009
Physics A	10%	10%	9%
Physics B	47%	29%	29%
Physics C	-	60%	61%
Total	57%	100%	100%

Source: UNI C Statistics and Analysis

Note: For the years 2005-2007, the average for the three years is shown. Number of pupils in total (N) (2005) = 16,993, N (2006) = 17,798, N (2007) = 18,561, N (2008) = 18,954, N (2009) = 21,217 (The number of pupils that are expected to complete the STX programme in the summer of 2009.)

The table illustrates a very minor decrease in the proportion of pupils choosing Physics at level A, but a significant decrease in the proportion of pupils choosing Physics B. In total, the proportion of pupils choosing either level A or B has decreased from 57% in 2005-2007 to 38% in 2009. This decrease is probably caused by the fact that Physics C is now compulsory for all pupils in STX, whereas Physics B prior to the reform was compulsory for all pupils on the Mathematics line in STX. However, other factors may also have affected pupils' choices, e.g. the supply of study packages at the schools.

Table 5

Subject combinations – STX

Combination	2006-07	2009	Change (percentage points)
Mathematics A + Physics A + Chemistry A	1%	1%	+0
Mathematics A + Physics and Chemistry – one at A level, the other at least at B level	10%	14%	+4
Mathematics A + Physics and Chemistry – both at least at level B	14%	25%	+11

Source: UNI C Statistics and Analysis

Note: For the years 2006-2007, the average for the two years is shown. Number of pupils in total (N) (2006) = 17,798, N (2007) = 18,561, N (2009) = 21,217 (The number of pupils that are expected to complete the STX programme in the summer of 2009.)

As Table 5 shows, there has been an increase from 14% to 25% in the proportion of pupils combining Mathematics at level A with both Physics and Chemistry at least at level B. Hence, achievement of the necessary combination to continue with university studies in the natural sciences, medicine or several engineering subjects has benefited in line with the ambition of the reform. For higher education programmes in Physics or Chemistry, which require Mathematics at level A and normally either Physics or Chemistry at level A and the other at least at level B, the proportion of pupils with the necessary combination has increased from 10% to 14%.

4 Development of the subject of Physics

This chapter focuses on the overall development of the subject of Physics in HTX and STX with regard to the identity and purpose of the subject and approaches to its teaching. The first section of the chapter is based on an analysis of the curricula before and after the reform. It outlines how the subject is defined in the new curricula and which approaches to the teaching are emphasised. The approaches to the teaching are revealed from the description of the subject identity and purpose, and from the curricula guidelines for the organisation of the teaching and pedagogic principles. Section two provides the expert panel's reflections on, and assessments of these developments from an international perspective.

This chapter focuses on the overall development of how Physics as a subject is perceived, whereas subsequent chapters go into more detail on developments surrounding the specific subject aims, content and examinations.

It is important to note that the new curricula should be seen as a continuation and reinforcement of a tendency that had already been occurring over an extended period of time. Seen in this light, the descriptions and reflections in this and the following chapters might tend to exaggerate the changes caused by the reform.

4.1 Subject definition and teaching approaches in the new curricula

Against the backdrop of the reform's intention of strengthening the natural sciences and providing them with an enhanced role within general education in the upper secondary education programmes, Physics has a central position.

Identity and purpose of the subject of Physics in HTX and STX

The new curricula place explicit emphasis on defining the identity and purpose of the subject in the respective programmes. The first sections of the curricula define the subject identity and purpose. These descriptions differ from HTX to STX. For each programme the identity and purpose is almost identical at levels A and B.

Although the subject identity is formulated differently in HTX and STX, both are centred on the combination of experimental and theoretical elements of Physics as a vital duality to stimulate curiosity for, and creativity within the subject. In HTX, the practical character of the subject is particularly emphasised, including the involvement of the pupils' own experiences with physical phenomena.

The profile of Physics in HTX has traditionally been, and still is characterised by a technological and practical focus, whereas in STX, a broader and more classical approach to the subject has evolved. However, the emphasis on current technological problems has also grown within the subject identity in STX, and insight into current technical-scientific issues within production is now explicitly included in the purpose of Physics education.

In both programmes, the identity and purpose of the subject reflects the position of Physics as a fundamental scientific subject, from where pupils are to obtain some broad scientific competences that can also be applied in other subjects as well. The pupils' familiarity with scientific methods and viewpoints is strongly emphasised in the new curricula, as is their understanding of our worldview in relation to the history of science and the connection between technology and society.

Approaches to the teaching of the subject

To some extent the new curricula place more emphasis on the notion that Physics should appear more interesting and relevant to the pupils. For instance, the STX curricula, at both levels A and B, state that in organising the teaching, emphasis should be placed on giving the pupils an opportunity to experience the subject as relevant, meaningful and exciting. In the HTX curricula, it is stressed that the subject be easy to relate to and that Physics is a subject that encompasses our own experiences of physical phenomena.

Generally, the HTX curricula emphasise that the teaching should be close to reality – it should be based upon the pupils' everyday experiences and involve topics from everyday technology. However, the former HTX curricula did also mention the pupils' experiences. In the new STX curricula, the perspective is less connected to the pupils' own experiences, but more to industry and research. It states in the STX curricula that part of the teaching should be organised so that the pupils come to work with real challenges that are based upon a specific company or research institute.

Closely connected to the experience of the subject as being relevant and exciting, is another aspect regarding the pupils' attitude towards Physics: the pupils' curiosity, creativity, openness and investigative attitude. This aspect of attitude is connected to the experimental work and the project based approach. Thus, in the STX curricula it states that the learning format should give the pupils the courage to develop and realise their own ideas and to cooperate with others. A crucial element of the learning formats is the experimental work, which should account for 20% of the teaching at both levels A and B. The pupils are to carry out at least one large project at level B and two at level A, where the pupils work in groups with an experiment they have chosen themselves. It is, furthermore, stated that the selected experiments should represent a progression in the demands placed upon the pupils' independence. In HTX, the investigative attitude is, among other things, to be developed through the pupils' work with an independent project concerning a physical, technological or technical problem chosen by the pupils themselves and involving investigation via experimental work and study of related theory. This project work was also part of the old curricula at both levels.

The new curricula entail new possibilities and requirements regarding interdisciplinary work in both programmes, although the change is most extensive in STX. The tradition of interaction with other subjects has traditionally been more prevalent in HTX. Besides the coordination with Mathematics, HTX already included technical and technological problems in the teaching, and Physics thus interplayed with technology. In the former STX curricula, however, only the coordination with Mathematics was required. The new curricula for HTX and STX have set the scene for a more widespread use of Physics in combination with other subjects. This includes Physics becoming part of the interdisciplinary courses – the *study programme* in HTX and the *general study preparation* and the *natural science basic programme* in STX. When Physics becomes part of a pupil's study package, the interaction with other subjects is further ensured through the planning of an interdisciplinary course within these subjects. If Physics is an elective subject, the pupils' knowledge and skills from other subjects should be employed in the Physics course. For HTX, it is stated that in the project work, Physics should generally collaborate with one of the following subjects: technology, a science subject, Mathematics or social science.

Finally, the requirement for integrating IT in the subject has been strengthened in the new curricula. Firstly, the curricula state that IT should be used in connection with the processing and presentation of data, e.g. from the pupils' own experiments. Furthermore, they state that IT should be used to search for information in conjunction with projects and elective topics. Finally, IT tools have been applied in the subject of Mathematics, and they are part of the pupils' mathematical skills applied in Physics. In the former HTX curricula, the use of IT was also stated, though the requirements are more detailed in the new curricula.

4.2 Reflections and assessments of the expert panel

Overall, the expert panel finds it very important to clearly define and maintain a distinct identity for the subject of Physics at upper secondary level. According to the panel, Physics is an essential subject, which has contributed and contributes enormously to mankind's perception of the world and to modern technology. The expert panel stresses that Physics is a core subject in science, and that it is important to define its fundamental character as well as its boundaries and connections with other scientific subjects. Therefore, the expert panel approves of the effort to clearly define the distinct identity of Physics in the new curricula as a fundamental scientific subject.

The expert panel considers that the approaches to the subject of Physics in the new curricula generally correspond to the general changes in the field of Physics within research, companies and universities. For example, modern IT now plays a central role in the work of most physicists – experimentally as well as theoretically. These tools entail new possibilities in relation to modelling and are important in relation to the processing of data, as well as to simulations and visualisations. Most areas of Physics are very dependent on computer science, and the importance of IT will undoubtedly grow in the future. Thus, from the panel's point of view, it is a rewarding and unavoidable development that IT is introduced in the subject of Physics in upper secondary education. IT serves as a modern learning aid, and it is important for pupils to gain an insight to its use in relation to Physics in research and industry.

The panel finds it important that the subject of Physics in upper secondary education keeps up with the general trends in Physics within industry and research. At the same time, however, the panel emphasises that it is important to balance modernisation elements with the traditional theoretical and pure aspects of the subject.

4.2.1 Making Physics relevant to the pupils

The expert panel notes a general trend in other European countries of stimulating pupils' excitement and positive views towards Physics. For example, the British "Institute of Physics" [6] located in London has established a programme called "Stimulating Physics"[7], with the purpose of increasing the number of pupils taking Physics at higher levels in upper secondary education. This trend is driven by deep concern about an increasing deficit of scientists with a strong background in Physics, something which is also discussed in a Danish context. The "Stimulating Physics" programme pilots different projects in order to motivate and catch the pupils. Among other things, the programme focuses on broadening the pupils' horizons beyond Physics in a school-context by bringing concrete examples of Physics and its applications into the teaching. The panel emphasises the importance of, and the need for making more pupils interested in Physics, and acknowledges that it demands continuous focus on ways to develop the subject and keep it relevant and closely connected to real world developments. Thus, the panel finds the enhanced focus on pupils' positive views towards Physics highly relevant.

In this context, the enhanced focus on realistic challenges from everyday life and everyday technology, which is very pronounced in the new curricula, is particularly in line with a wider international trend that places more emphasis on conceptual Physics rather than mathematical Physics[8]. The traditional approach to teaching Physics is to lay out definitions, facts and concepts, and explain the relation between them – all something you can do on a blackboard or with pencil and paper. In contrast, conceptual physics emphasises comprehension of fundamental concepts, theories and laws rather than mathematical language and computation. Conceptual Physics emphasises the "hands on" element of learning Physics, and that the teaching should relate to pupils' own conceptions of Physics from their everyday life. The panel acknowledges that conceptual Physics is valuable for teaching Physics, as it stimulates pupils' motivation, curiosity and un-

[6] *The Institute of Physics is a scientific charity devoted to increasing the practice, understanding and application of physics worldwide. (http://www.iop.org/aboutus/index.html)*

[7] *http://www.stimulatingphysics.org/*

[8] *See for example Paul Hewitt: "Conceptual Physics" or Jon Ogborn: "Science and Commonsense" in Matilde Vicentini and Elena Sassi (ed): "Connecting Research in Physics Education with Teacher Education"* published by the International Commission of Physics Education.

derstanding of the subject, and consequently it should be present in the Danish curricula. However, the panel finds it important that conceptual Physics is supplemented with fundamental and theoretical physical knowledge, including Mathematics as a language for describing natural phenomena. The panel finds the introduction of cooperation with a local company or research institute in the STX programme particularly promising. It is the panel's impression that, in an international context, it is common to include visits to research institutes or companies in the Physics teaching. However, the scope of this aspect seems relatively wide in the Danish curricula. Thus, it may not yet represent a strong international trend, but the panel finds this initiative commendable.

4.2.2 Interaction with other subjects

Looking at Physics in a worldwide context, the expert panel identifies a trend toward increased interdisciplinarity. More and more physicists tend to work with scientists from other disciplines, in particular from Mathematics, computer science, chemistry and biology[9]. This development within universities and companies reflects the fact that old boundaries between the disciplines are fading away. The expert panel finds that these developments should be reflected in Physics courses at upper secondary level. The integration of an interdisciplinary approach is important in order for pupils to make better-informed choices of further education. In addition, it stimulates pupils' insight into interdisciplinary problem solving, which is expected to be increasingly required by the labour market as well as in higher education.

However, the panel underlines that the increasing focus on interdisciplinary aspects enhances the importance of defining the subject of Physics independently, especially at upper secondary level. In order to take part in interdisciplinary projects in a scientific education or career, the pupils must possess fundamental skills within the field of Physics in its pure form. Thus, the expert panel stresses that a balance between pure Physics and Physics in combination with other subjects is very important in upper secondary education. The individual pupil needs to master the discipline and understand fundamental laws of Physics in order to be able to work interdisciplinarily at a reasonable level.

The interdisciplinary approach involves both interaction with other natural sciences – and technology in HTX – and interaction with subjects from other faculties: social science in both programmes and the humanities in STX. Interaction with other natural sciences and technology is, according to the panel, very natural and relevant, especially for those pupils interested in continuing with further scientific or technological studies and careers.

Interaction with subjects from the other faculties is connected to the emphasis on putting Physics into a wider perspective and understanding its contribution to historic, cultural and societal development. According to the panel, this kind of interdisciplinary work is certainly relevant. However, it might entail other and greater challenges. In this respect – without knowing about the actual implementation – the expert panel stresses that the selected topics in the subject combinations must be feasible and sensible.

In this context, the expert panel considers it to be a great advantage of the Danish system that Physics as a compulsory subject at C-level has been introduced in STX. This implies that all pupils in the STX programme will be familiar with Physics as a distinct subject. In other European countries, the extent to which the compulsory level of Physics remains a distinct subject at upper secondary level differs, but the panel has observed a trend where Physics is included as part of a common natural science subject – as was also the case for the former language line at STX in Denmark. The panel wishes to underline the importance of Physics being a distinct subject in order to ensure an adequate competence level in Physics.

[9] *This trend is for instance considered by Jon Ogborn: Physics Now, Reviews by Leading Physicists in the International Union of Pure and Applied Physics, 2004. (http://web.phys.ksu.edu/icpe/Publications/PhysicsNowText-A4.pdf)*

Approaches to the subject – key findings:

- Overall, the expert panel approves of the general modernisation of the subject of Physics. It is adequate and largely in line with international trends.
- According to the panel, the enhanced focus on pupils' views towards Physics, which is prevalent in the Danish curricula, is in line with an increased international awareness of the need to stimulate Physics. The same applies to the focus on making the subject relevant to pupils by involving experiences from their own everyday lives as well as other real challenges, e.g. from industry. The expert panel approves of these approaches to the subject, including a more conceptual approach to Physics. However, at the same time, the panel finds it important to maintain focus on more theoretical and mathematical aspects of the subject.
- The expert panel assesses that the interdisciplinary approach is fruitful and corresponds well to the increased interdisciplinarity seen in research and technology. However, the panel emphasises that it is important to develop the pupils' fundamental Physics skills in order for them to contribute to, and fully benefit from the interdisciplinary work.
- The expert panel emphasises that Physics is a core subject among the natural sciences, and that it is important to define and maintain a distinct identity for the subject in upper secondary education. The introduction of compulsory Physics at level C in STX is an example of very good practice in a European context, and underlines an ambition of strengthening general education in the natural sciences.

5 Subject aims and content

This chapter focuses on the development in the subject of Physics with regard to the subject aims and the subject content. The first section outlines the subject aims and subject content in the new Danish curricula and focuses on the development identified when comparing the curricula before and after the reform. The second section presents the panel's reflections and assessments regarding the relevance and development of the subject aims and content.

5.1 Subject aims and content in the new curricula

Overall, the new curricula place more emphasis than the former on describing the subject aims in terms of the competences that pupils are to achieve. At the same time, the level of detail in defining the content is reduced. Instead of being the defining core of the curricula, content is rather a means to achieving the subject aims. This entails an increased emphasis on management by objectives, as opposed to management by content, and to some extent sets more focus on the pupils' skills and competences, i.e. what the pupils should be capable of doing with their knowledge. Skills and competences are listed as subject aims, and are generic, which implies that they are not coupled to specific topics within Physics.

The subject aims are supported in the curricula by guidelines for pedagogic principles and learning formats. This reflects the idea that the subject aims cannot be fulfilled solely through defining the content but also depend on teaching approaches.

5.1.1 Subject aims in the new curricula

There are differences between the formulations of the subject aims listed in the HTX and STX curricula. However, they largely involve the same trends regarding the kinds of competences which are highlighted. Differences between the two programmes exist, however, regarding the extent to which different competences are stated explicitly. For instance, insight into the fundamental laws of Physics is stated explicitly in the subject aims of the HTX curricula, but not in the STX curricula.

The subject aims reflect an ideal for the competences to be achieved by the pupils at the end of the course. So, it is not expected that all pupils completely fulfil the aims.

Below is a condensed list of the Physics aims for the two programmes. A detailed overview of the aims at levels A and B for HTX and STX, respectively, is provided in the subject curricula in appendices C-F.

Models

A central competence in the subject aims for both HTX and STX is to analyse and assess physical problems based upon the concept of models. In HTX, pupils at level B should be able to give an account of the use of physical concepts and models in realistic situations, including their use in industry or the pupils' everyday lives, whereas pupils at level A should be able to analyse and assess problems based on the concept of models and give an account of the application of the models within a technical and technological field. In STX, the pupils at A and B level should be able to know, set up and use a wide selection of models to explain physical phenomena, and in addition pupils at level A should be able to discuss the conditions under which these models are valid.

Experiments
The pupils' experimental skills are emphasised in the subject aims in both of the programmes. In HTX, it is a subject aim that the pupils, at different levels in Physics A and B, should be able to plan and carry out different types of physical experiments, and use fundamental laws of Physics in the experimental work. In STX, the pupils should be able to plan, describe and carry out Physics experiments based on a given problem (level B) or an open-ended problem (level A).

Calculation and data treatment
In STX, emphasis on fundamental skills is emphasised with regard to calculating and analysing Physics problems. At B-level the pupils should be able to undertake calculations of physical quantities based on fundamental concepts and models. At A-level the pupils should be able to analyse Physics problems using different representations of data and, furthermore, deal with experimental data and discuss the mathematical connection between different physical quantities. In HTX level A and B, the pupils should carry out large experiments that require measurements, calculations and assessments.

Physics in a wider perspective and interaction with other subjects
The ability to put Physics into a wider perspective is a pivotal point in the subject aims in both programmes. At both levels A and B in HTX, the pupils should be able to put certain areas of Physics into a historical and technological perspective, and pupils at level A should, furthermore, be able to put their knowledge of Physics into a wider perspective in working with their areas of interest. In STX, pupils at both levels should be able to put Physics into perspective via examples and interaction with other subjects. With regard to this aspect, the pupils in both programmes should be able to understand the scientific methodology in a wider perspective and know when it is relevant to apply it. Moreover, as stated in the HTX curriculum the pupils should be able to use this knowledge to tackle new areas of Physics. Knowledge of the scientific methodology is very explicitly stated in the subject aims in the HTX curricula – with a difference in progression between levels B and A. In the STX curricula, it appears more implicitly in the subject aims, but is clearly stated in the section describing the purpose of the subject. The subject aims in STX, however, stress that the pupils should be able to identify scientific elements in the media and assess the scientific validity of the arguments.

Communication
One development from the former to the current curricula is the introduction of subject aims regarding communication and scientific argumentation. In HTX, it is an aim that the pupils should be able to substantiate and communicate results of their experimental work at both level A and B; and in STX, pupils at both levels should be able to present a topic containing Physics material to a chosen target audience.

In comparing the former and the new curricula, it appears that most aspects in the current subject aims were also covered by the former curricula. However, some differences can be identified. Firstly, the emphasis on the competence of knowing and understanding central areas within Physics is more explicitly prevalent in the former curricula than in the current. Secondly, there are areas that are present in the former curricula, and further emphasised in the new. For instance, experimental skills as well as the capability to use and discuss models to explain physical phenomena and solve Physics problems had a central position in the former curricula, and these are further emphasised in the current curricula. In addition, the former curricula focused the pupils' understanding of scientific methodology and their ability to put Physics into a wider perspective, which are competences that have become sharper in the new curricula. Especially the HTX curricula reflect a development in this respect. The STX curricula, though, place particular emphasis on the pupils' ability to understand and discuss scientifically and technologically based arguments, and, as specified in the new STX curriculum, the pupils should be capable of reading documents from the media, identifying the scientific elements and assessing their validity. Thirdly, the pupils' communicative competences within Physics have been emphasised in both programmes.

5.1.2 Subject content in the new curricula

In contrast to the former curricula, the content in the new curricula is divided into core material and extension material in both programmes, which implies more freedom to choose between different topics and materials. The core material is compulsory, whereas the extension material is elective. This should firstly be seen in relation to the development towards management by objectives. Secondly, the extension material is intended to include specific content and topics which are suitable for the interdisciplinary projects in the specialised study programmes and to support the pupils' ability to put Physics into a wider perspective. Thus, in STX, the extension material should include current or socially relevant problems, including physical or technological aspects of sustainable development. Finally, the purpose is connected to the emphasis on making Physics relevant and interesting to each individual class. In HTX, for instance, it is highlighted in the curriculum that the pupils should be able to work with their own fields of interest and current technological problems.

The extension material is chosen by the individual teacher and class within the broad guidelines of the curricula. In HTX the extension material should account for approximately 35% of the material at level A and approximately 20% at level B, whereas the extension material in STX accounts for 30% of the material at level A and 25% at level B. The former HTX level A curriculum included elective topics that should have accounted for approximately 30%, but were to be chosen within predefined areas.

The subject still contains a substantial element of core material, as the written examinations are national. Since the examinations are common to all pupils in a year group, a certain amount of core material is required.

Core material in the former and the present curricula

In the former curricula, the content was divided into headings of main topics. In HTX, levels B and A in combination[10] covered the following headings:

- Wave theory;
- Electricity;
- Mechanics (expanded if studying level A);
- Thermodynamics (expanded if studying level A);
- Electromagnetism (only at level A).

Each heading was followed by a list of topics, phenomena and laws to be included, along with a description of the level of knowledge that the pupils were expected to achieve within each area.

The content in the new HTX curricula is no longer grouped under a number of content headings, but is stated in a number of different descriptions. However, the descriptions lie within the same content areas as previously. As an example, the first point in both A and B curricula is, "The fundamental laws of kinematics and dynamics, Newton's laws, energy and work". There are 9 such bullet points at level B and 16 at level A (which include the points from level B). The progression from level B to A has not changed dramatically with respect to the content areas that are expanded at level A. The progression still lies within the fields of mechanics and thermodynamics, e.g. in the fact that the first and second laws of thermodynamics are included in level A and not in level B. Furthermore, electromagnetism is still included solely at level A. However, a progression is introduced between the levels with regard to wave theory: level A, in contrast to level B, now includes harmonic waves, the fundamental concepts of wave theory, refraction and interference. The new curricula, however, do not specify the amount of teaching allotted to each of the areas, as did the former HTX curricula.

In STX the overall topics covered at levels B and A in the former curricula were:

- Heat (including thermodynamics);
- Electrical circuits;
- Waves;

[10] Before the reform, pupils began by studying level B (compulsory in HTX and in the Mathematics line in STX) and afterwards they could opt for level A. The former curriculum at level A thus builds upon the compulsory level B.

- Atomic and nuclear Physics (expanded if studying level A);
- Mechanics (expanded if studying level A);
- Electricity and magnetism (only at level A).

In the new curricula the topics are:
- Physics' contribution to the scientific world view;
- Energy;
- Electric circuits;
- Waves;
- Quantum Physics (expanded if studying level A);
- Mechanics (expanded if studying level A);
- Physics in the 21st century (only at level A).

Thus, the development of the content areas has been more significant in the STX programme than in HTX. Firstly, a new more generic content area has been introduced at both levels in STX called "Physics' contribution to the scientific world view". It includes among other things a basic outline of the current description of the universe and its development, the Earth as a planet in the Solar system and nature's smallest building blocks, including the Physics of atoms. Furthermore, the new curricula contain a heading called energy, whereas the former curricula contained the heading, heat. These headings, however, cover some of the same content areas. Quantum Physics certainly covers the former atomic and nuclear Physics.

The overall progression between levels A and B has largely remained the same as in the former curricula, insofar as quantum Physics and mechanics are the content areas that are elaborated at level A. However, electromagnetism is no longer part of the core material at level A. The new topic called "Physics in the 21st century" now differentiates the two levels. It covers a topic which is determined by the Ministry of Education and is announced each year before the start of the final year. This year's theme was, "The laser – the modern light source". The introduction of this periodically changing modern topic in the core material is intended to establish a window to the Physics currently occupying research and industry, which should inspire visits to companies or research centres.

5.2 Reflections and assessments of the expert panel

This section presents the expert panel's reflections and assessments regarding the subject aims and content, and the relation between the two. The discussion is divided into three subsections. The first section deals with the way of describing what the pupils should learn. It includes a discussion of the balance between defining aims in terms of competences versus defining content. In this connection, it touches upon the level of freedom permitted locally to choose which content is most appropriate in order to achieve the overall aims. The second section presents the expert panel's assessment regarding the relevance of the subject aims. Finally, the third section outlines the expert panel's discussions regarding the relevance of the content covered in the core material.

5.2.1 Aims and competences versus detailed content descriptions

According to the expert panel, the increased focus on competences, rather than a detailed syllabus, is in line with the development within the subject of Physics in many other European countries. Furthermore, the concept of competences is a pivotal point in the educational framework in the European Union and the Bologna Process. However, it is the panel's impression that the clarity of the division between content and competences varies across the countries. Similarly, there are differences in the extent to which local variation is permitted with regard to content being taught. In Norway for instance, extension material has been part of the curricula previously, but no longer is. In Sweden, extension material is included in relation to project work which aims at developing the skills of planning, structuring and taking responsibility for a large piece of work, and providing experience of the project working form. In the UK, extension material is included in the form of coursework, where pupils are supposed to carry out practical investigations of topics chosen by the pupils themselves. It is the impression of the expert panel that Denmark lies on the edge of the scale regarding this development, having emphasised a division between competences and content in the Physics curricula, and allowing a high degree of freedom to choose content locally.

The expert panel underlines that the concept of competence is a useful base for the curricula, and that the competences the pupils are to achieve during the course are very sensible. It is important not to solely define the content that the pupils are to achieve knowledge of, but also to state explicit aims for how the pupils should use this knowledge at a generic level. However, the panel sees some challenges with regard to the focus on more open-ended subject aims and competences rather than on detailed content descriptions. It might, from the panel's point of view, be difficult to grasp what precisely the formulations of the competences cover, thus leaving significant room for interpretation due to the possible lack of any developed traditions in this regard. The panel assesses that this, on the one hand, provides an opportunity to create flexibility and motivation locally, while on the other hand, there is a risk that the focus on competences entails a lower degree of overview of what should be taught in the subject. Consequently, the panel stresses that the description of competences should be supplemented by description of subject content. The expert panel finds it important that it is made clear to teachers which areas of Physics should be taught and at which level, e.g. with regard to specific laws, concepts and equations. The expert panel recognises, though, that other sources of information, e.g. the teaching guidelines, may also contribute to this purpose.

From the panel's point of view, the division into core and extension material in the new curricula entails valuable elements in terms of local motivation, flexibility and opportunities for interdisciplinary work. Therefore, the panel finds it appropriate that the curricula contain extension material. However, the expert panel questions whether the core material constitutes a sufficient proportion compared to the extension material to ensure a uniform competence level for the pupils, and, furthermore, why the amount of extension material varies from 20 to 35% when comparing programmes and levels.

5.2.2 Relevance of the subject aims

The general aim of the HTX and STX programmes is twofold: to prepare pupils for higher education, and at the same time to ensure general education. This duality permeates the programmes in their entirety as well as the individual subjects. The panel emphasises that it is important that this dual aim is reflected in the subject aims in order to meet the needs of both the majority of the pupils (general education) and the substantial minority (preparing for higher education that involves Physics). Therefore, the relevance of the subject aims should be assessed in relation to this dual purpose of the subject.

Generally, the expert panel assesses that the subject aims in both of the programmes are relevant, ambitious and comprehensive. In addition, the panel assesses that the differences between levels A and B as they appear in the curricula are adequate. The differences reflect a graduation in the level of competences that match the differences between the levels A and B. However, the panel wishes to comment on the balance between the different kinds of competences in the curricula.

The panel makes a distinction between fundamental core competences in the subject on the one hand, and broader communication competences and the competences of putting Physics into perspective on the other hand; both types of competences being represented in the curricula. From the point of view of the panel, the fundamental core competences include, firstly, knowledge of the core content areas of the subject, including central concepts, laws and formulae; and, secondly, competences that build on mathematical skills, including calculating skills and the capability of using models to analyse and solve Physics problems. The broader competences include understanding of scientific methodology; communication skills; the ability to put Physics in a wider perspective and to understand its contribution to the worldview and its interaction with culture, technology and society; and finally skills that involve discussing and assessing scientific findings. The panel stresses that both kinds of competences should be present in the subject curricula.

Core competences of the subject

Looking at international trends, modelling is a keyword in Physics curricula, and one which is continuously emphasised. In this perspective, the Danish curricula follow the international trends. According to the panel, this is a natural development, as mathematical modelling is a crucial fundamental skill in the subject of Physics, which makes it possible to attack even difficult types of problems. In addition, it is an important competence in relation to further scientific education, and is increasingly important in relation to ongoing technological developments. In this connection, the panel underlines that the competence of setting up and using models to analyse and solve physical problems places demands on other competences and, therefore, cannot be regarded as being separate from the aim that the pupils should be capable of assessing the area of validity of a model and maintaining a critical approach to the use of models. This is a strength of the subject aims in the curricula.

Also, the subject aims regarding planning and carrying out experiments are from the panel's viewpoint up to date and comprehensive. It is, according to the panel, important that the competences connected to the phases before and after the experimental work are covered in addition to the competences connected to carrying out the experiment. Thus, the panel stresses that the phase prior to the experiment is important, e.g. the independent planning of the experiment. Here, it is central that the experiments do not become purely a matter of following a fixed instruction, and that they are linked to theoretical problems. The phase after the experiment is equally important, as it includes calculating and dealing with data as well as documenting and communicating the results. Thus, with regard to skills within modelling and experiments, the Danish curricula are adequate, according to the panel.

The expert panel stresses that mathematical calculating skills are also important. The panel is in general concerned about calculation skills of pupils in Europe and whether they correspond to pupils' skills in some Asian countries[11]. In this context, the panel stresses that the value of mathematical calculating skills must not be underestimated.

The panel appreciates that insight into the fundamental laws of Physics is an explicit subject aim in HTX. In this context, the panel has considered the differences in formulations of the subject aims in the two programmes. The panel recognises that Physics has different profiles for the two programmes, which should be reflected in the subject aims. However, some core aspects of the subject are common to the two programmes and the expert panel would, therefore, consider it advantageous if these parts had similar or identical formulations. This would allow pupils and other stakeholders to gain a clearer understanding of the intended competences.

Communication and putting Physics into perspective

The expert panel considers the emphasis on broader competences to be in tune with international trends in the subject of Physics in upper secondary education – especially among the western countries. Within science education in general and also within Physics education, there has been significant focus on the nature of science as part of science and Physics courses, and not only on content knowledge. A prominent feature in this connection is the claim that Physics education should include knowledge *about* Physics as well as knowledge *in* Physics[12]. Furthermore, the broader competences, such as communication skills in relation to science and putting science into perspective, are gaining increased attention internationally. These competences are transferable to many areas of research and are also valuable to a further scientific career. Furthermore, there is a growing international focus on the importance of teaching for scientific literacy and science culture for the majority of pupils who, while they will not pursue a scientific career, are part of a society where science and technology play a crucial role in development. In this context, the

[11] Based on the panel members' experiences with Asian exchange students and knowledge of physics Olympics' results. However, it must be noted that within the scope of this evaluation it has not been possible to investigate this further with regard to the standard of reference when comparing the level of skills.

[12] See for example: Millar, R. & Osborne, J. (Eds.) (1998). Beyond 2000: Science Education for the Future. London: King's College, School of Education; Ryder, J. (2001). Identifying science understanding for functional scientific literacy. Studies in Science Education 36, 1-44; and Talisayon, V. M: Development of scientific Skills and Values in Physics Education

growing international perspective on sustainable development is an example of the need for general scientific education and the need for these kinds of competences.

Thus, the enhanced focus in the Danish curricula on the pupils' ability to communicate and understand the scientific methodology in a wider societal and cultural perspective is in line with developments abroad. According to the expert panel, these are all important competences, especially in order to fulfil the general education aim and to motivate the pupils. This is a part of the development of the subject of Physics that, in the view of the panel, should receive full support.

At the same time, the panel finds it important to balance the core Physics competences, which are specific to the subject of Physics, with broader more generic competences within the natural sciences, pupils' preparedness to continue with further study and general education, aspects which are also relevant to the subject. According to the expert panel, it is crucial that pupils acquire knowledge of the core subject as a foundation for developing the broader competences.

5.2.3 Relevance of the subject content

Overall, the expert panel considers the content of Physics defined by the core material to be relevant in both of the programmes and to correspond adequately to the subject at upper secondary level in other European countries. The content in both HTX and STX covers vital parts of Physics, such as energy, mechanics, waves, etc. However, the panel notes that the reform in some areas has increased the difference in content between the two programmes, due to the changes made to the content in the STX curricula.

The introduction of the topic "the contribution of Physics to the scientific worldview" is limited to the STX programme. However, this reflects the difference in the Physics profile for the two programmes, and the expert panel thus finds it reasonable. The STX programme traditionally targets a broader group of pupils and, therefore, the general educational and cultural aspects of the subject are more apparent. The HTX programme still has a profile that is more connected to industrial and technological aspects. The tendency of placing more emphasis on astrophysical topics at upper secondary level is, according to the panel, not solely a Danish trend, but is emerging in a number of countries as part of an effort to make Physics interesting to more pupils. Astrophysical topics are often very popular. As a motivating factor, the panel finds it relevant to emphasise astrophysics in the STX curricula.

Balancing classical and modern Physics

The other major innovation in the STX core material is limited to level A, which introduces the forward-looking topic, "Physics in the 21st century". This should be regarded as part of an effort to render Physics in STX more modern and connected to new technological aspects, and it thus counteracts some of the difference between the profiles of HTX and STX. The panel finds it interesting to consider the balance between classical and modern Physics, which is a discussion connected to Physics curricula taking place in other European countries as well. It is the panel's impression that there is an international awareness of the need for involving more modern Physics at upper secondary level. It is first of all a great motivation for the pupils, as it shows that the subject is dynamic and that it has perspectives connected to further education and commercial careers. Thus, the expert panel assesses that the new topic is a positive development in the subject.

The expert panel suggests that the modernisation of the subject could permeate the content more broadly than just introducing this new topic, e.g. with regard to the topic, electric circuits. The core material at both levels A and B states, "simple electric circuits with steady current". The expert panel suggests that this topic be developed further in the curricula to include, for instance, alternating current and elements of electronics. Electronics is more modern than electric circuits, and important devices like diodes or a transistor could profitably be introduced into the curricula.

According to the expert panel, there are many open questions within the field of Physics, including unsolved 'mysteries', which the pupils could benefit from touching upon, although many of these are too difficult to teach more thoroughly at upper secondary level. 'Hot' topics such as entanglement, dark matter or gravity waves, could profitably be used as motivational factors in the teaching. However, the expert panel finds it again important to strike an adequate balance between classical and modern Physics and emphasises that solid knowledge within classical Physics is crucial.

The coverage of the content
The expert panel finds that the introduction of new and more modern topics in the STX curricula in combination with the reduced amount of compulsory core material have some unfortunate consequences, because some central topics are no longer included in the core material.

Firstly, the expert panel notes the fact that electromagnetism is no longer included in the core material in STX (at level A). From the panel's point of view, electromagnetism is a key topic of Physics, which plays an important role in the everyday life of the pupils and in modern technology. It is part of the "toolbox" that the individual pupil needs, partly to understand everyday phenomena such as light, electro motors, etc., and partly to be prepared for further scientific education. The panel recognises that electromagnetism could be included as a topic in the extension material, and that it has been left out of the core material in order to gain flexibility and room for going into depth with other topics. However, the panel considers it important that all pupils acquire at least some basic knowledge within the field of electromagnetism – a cornerstone of Physics and technology, and in addition discovered by a Dane, H.C. Ørsted.

Furthermore, the expert panel considers thermodynamics to be an important element, which is no longer mentioned directly in the STX curricula, but presumably included under the heading of energy. Hence, while the first law of thermodynamics might usefully be included, the panel wonders whether other valuable elements like the ideal gas law need be included. The expert panel recognises that, for example, Norway has left out almost all thermodynamics in the compulsory material; thus such exclusion is not unheard of internationally.

Subject aims and content – key findings:

- According to the expert panel, the increased focus on aims and competences rather than a detailed syllabus is in line with the development within the subject of Physics in other European countries. The expert panel underlines that competence is a useful concept in the curricula as it describes how the pupils are able to use their knowledge of the subject. At the same time, the expert panel finds it important that the description of competences is supplemented by content descriptions in order to clarify the specific level of the teaching.

- The panel finds it important to strike a balance between core Physics competences and broader competences in terms of communication and putting Physics into perspective. The panel approves the fact that the fundamental core Physics competences with regard to modelling and experimental work are covered in the curricula. The competences regarding general scientific methodology, communication and the ability to put Physics into a wider perspective are relevant competences for achieving especially the aim of scientific general education, and are in line with the focus in other European countries.

- Overall, the expert panel considers the core material in Physics to be relevant in both of the programmes and to correspond adequately to the subject at upper secondary level in other European countries. The expert panel welcomes the innovations to the STX core material. "The contribution of Physics to the scientific worldview" is appealing to most pupils and supports the general education aspect. "Physics in the 21st century" entails an innovative and forward-looking aspect. However, the expert panel notes that the introduction of the new topics and the extension material limits the core material; with the consequence that electromagnetism is no longer part of the compulsory material at level A in STX, which the panel regrets.

6 Examinations

In this chapter, innovations regarding the examinations in Physics for the two programmes are described. Furthermore, the expert panel's discussions and assessments of these innovations are presented. Besides looking at the development of the examinations which emerge from the curricula, the expert panel has looked into selected test sets used in the written examinations at level A.

The expert panel has compared and discussed selected test sets used before and after the reform, and considered their level of difficulty, the content represented and the types of competences and skills tested. The analysis and assessment of the test sets is important, as it must be assumed that there is a strong correlation between the required competences and level of the test sets and the focus during the teaching. The test sets are thus to some extent indicators of actual development in the subject and the level and scope of competences that the pupils are expected to achieve.

6.1 Examinations after the reform

The evaluation of the pupils comprises, like it did before the reform, a written and an oral examination at level A in both programmes, and an oral examination at level B. The written and oral examinations in Physics have been adjusted. This section outlines the adjustments made in the written and oral examinations.

Oral examinations

The alteration to the oral examinations supports the fact that Physics is an experimentally driven science.

In HTX, the oral examination has been altered at both levels A[13] and B. The new oral examination is based on experiments carried out as part of the preparation for the examinations. The pupils have 24 hours to prepare for the examination, during which time they, in groups of up to four pupils, carry out one or more self-selected experiments that illustrate a problem within a randomly selected field. The experiments as a whole may take a maximum of 6 hours. In addition, the examination is based on either the pupil's independent project or, at level A, one of the two elective topics that the extension material should contain. The examination itself is individual, with an allotted time of 30 minutes.

Also in the STX programme, a new experimental element has been introduced to the oral examination in both Physics A and B. However, whereas for HTX it is part of the preparation for, and the basis of the oral examination, for STX, the experimental part forms an actual examination where internal and external examiners will talk with the individual examinees about the specific experiments they are carrying out and the related theory. Thus the examination is now divided into two parts. The first part (1.5 hours at level B, and 2 hours at level A) is experimental. The examinees work in groups of maximum 3 pupils with an experiment, which could be a variant of a problem that has been included in the teaching, and they use experimental equipment which is also known from the teaching. However, pupils are to work with new data from the particular

[13] *However, at level A, it has been possible for the schools to choose the former oral examination type without the 24 hours of preparation time and experiments. Instead, the examination is based on either the pupil's independent project or one of the two elective topics. In addition, it includes a question that is centred upon one of 12 selected experiments from the teaching, which together cover the majority of the core material.*

experiment. The second part is individual, and the examination questions touch upon mostly theoretical Physics topics. Pupils at both levels have 24 minutes of preparation, and 24 minutes are allotted for the second theoretical part of the examination. Previously, there was an oral examination (30 minutes) consisting of two questions, one mainly experimental and one mainly theoretical. No actual experimental work was included in the examination.

Written examinations
For both HTX and STX, there is a written examination in Physics at level A only. All pupils at level A are normally evaluated by answering a written test set consisting of a number of exercises. The test sets are national and thus identical for all pupils in a year group. A central exam commission – one for HTX and one for STX – composes the tests sets. The written examination lasts 5 hours, which is an extension from the former four hours.

The use of tools and technology is another area in which the written examinations have changed. In HTX, a new kind of exercise has been introduced where the pupils use data from a CD-R[14]. This new type of exercise involves working with large electronic datasets, which is an element that could not have been included in the test sets prior to the reform.

In contrast to HTX, the use of technology in the written examinations in STX does not include working with electronic data. However, the use of CAS is also compulsory in the STX programme and is also a new approach in Mathematics.

6.2 Reflections and assessments of the expert panel

This section outlines the expert panel's reflections and assessments regarding the examinations in Physics for HTX and STX. Their discussions are divided into three subsections: examination types; content and competences tested; and level of difficulty.

The expert panel stresses that test sets can vary greatly from year to year, which should be taken into consideration in relation to the conclusions regarding the coverage of content and competences as well as the level of the selected test sets.

6.2.1 Examination types

Overall, the oral examination is, according to the expert panel, comprehensive and suitable for evaluating the subject aims stated in the curricula. It creates good conditions for evaluating pupils' understanding of the material and their ability to use and apply Physics independently. The panel has not had the opportunity to see examples of the questions posed in the oral examinations. The panel notes that many countries have only written exams at this level, e.g. the UK, but it is the impression of the panel that the focus on written exams has weakened in recent years, at least in some countries, probably as the result of increased focus on oral communication and argumentation skills. Considering the increased focus on pupils' understanding of the nature of science and conceptual Physics, the panel believes that the oral examinations are appropriate if these competences are to be evaluated in a meaningful way.

It is the panel's impression that the use of an experimental part in the examination itself – with external examiners – is less common in an international context; rather the pupils' experimental work is assessed internally. On the other hand, the experimental part of the exam is not unique to Denmark but is used in other countries, e.g. Norway. The expert panel believes that the importance of practical work in Physics education and the emphasis on using experiments in the teaching makes it natural that experimental skills are tested in the examination. For this reason, the expert panel finds the alterations to the oral examinations to be relevant; including a prolongation of the exam for STX and a prolongation of the preparation time for HTX. However, the panel expresses some concern regarding the total duration of the examinations (including the preparation time in HTX), although the panel has duly noted that the key persons interviewed – from both programmes – did not share this concern on basis of their initial experiences with the examination.

[14] *An example of this is task 2 in the test set from 2008, "Electric boat".*

The expert panel generally assesses that the written examination at level A is suitable for testing the pupils' competences. The curricula for both HTX and STX create a connection between the teaching and the tasks in the test sets by stating that the teaching should prepare for the test sets. The panel approves this connection and considers it important that the pupils during the teaching are made familiar with the kinds of tasks that they can expect to meet in the examination.

The expert panel assesses that the open-book examination, which allows the pupils to use different aids, including IT, allows room for a creative approach to the tasks. Furthermore, the open book examination is good as it sets up realistic conditions which compare to the situations that the pupils will meet in their further education and professions. The representative of the exam commission for HTX supported this argument, as he explained that the pupils are used to applying these tools in the teaching and in their everyday life: "It's their approach". However, the panel is concerned that a completely open book exam will not test whether the pupils have acquired sufficient basic knowledge, e.g. do they know Newton's laws by heart.

With regard to the use of IT in the written examinations, there is a difference between HTX and STX. In STX, the test set from 2008 is constructed in a manner that requires the use of the IT-tools used in Mathematics, whereas the HTX test set to a greater extent sets the scene for the use of computers, as it contains questions in which the pupils are supposed to use a dataset from a CD-R. The expert panel considers whether it would also be possible to include IT-based data in the written examination for STX, which would of course also require the integration of IT in the teaching. In this connection, the panel accentuates task 2 in the HTX test set as a good example that reflects an adequate amount of data treatment. The panel emphasises, however, that the amount of data treatment should not go further than in this example, as it would be too time consuming.

6.2.2 Content and competences tested

The selected test sets illustrate changes which are in line with the development of the curricula. There is a difference between the new test sets and the former inasmuch as the former are more traditionally constructed and the new are more innovative. Generally, the test sets in HTX and STX differ significantly, which reflects the difference between the subjects of Physics in the two programmes: STX has an academic/ scientific profile, whereas HTX aims at engineering. Hence, the test sets in HTX have a more technical focus than the test sets in STX, in accordance with the profiles of the two programmes.

One development is that the new test sets from 2008 for both programmes have more contextual description than the previous test sets. This is consistent with some of the competences which are in focus in the new curricula, for instance the pupils' ability to identify Physics elements in a text – mostly emphasised in STX – and to analyse Physics problems and set up models using relevant information, which is in focus in both programmes. On the one hand, the expert panel recognises that the context description can motivate the pupils by making the exercises more realistic; on the other hand, the expert panel is concerned that the larger amount of text is an obstacle for poor readers – who might have the potential to develop into excellent future physicists or engineers – and, furthermore, that the tasks can be solved without reading the contextual descriptions and, thus, might entail a unnecessary level of confusion. The panel assesses that not all the supplementary text in the selected test sets that the panel has been looking through provides relevant information in order to set up and use models with the right formulae, etc.

Another distinct development in the test sets, and one which is mostly prevalent in the STX programme, is a more open-ended approach to the questions and a focus on explanations and arguments. Thus the newest STX test set emphasises the competence of making and using assumptions. According to the expert panel this is a positive innovation, provided the pupils have practiced this thoroughly in the teaching. However, the panel emphasises that it is important to clarify in the test sets when the pupils are supposed to make assumptions themselves, and when they should use the given assumptions. The element of making assumptions is less pronounced in the HTX set. In the 2008 test set for HTX, all the constants are listed on the first page, whereas the test set for STX often requires that the pupils find them in their textbooks or other compendia.

6.2.3 Level of difficulty

In the assessment of the level of difficulty of the test sets, the expert panel emphasises, on the one hand, that a high level is naturally desirable. On the other hand, the panel stresses that the level in the test sets should reflect a realistic picture of the pupils' acquired competences, i.e. they should allow for the majority to pass and a certain proportion of pupils to obtain a high grade. This is in line with the objective of the international ECTS-standardisation. According to this, 35% of the pupils should, in general, obtain a high grade (25% should obtain grade 10, and 10% grade 12) and there should be a predominance of the average grade, 7, which 30% of all pupils should obtain. The ECTS-standardisation does not, however, take into account the pupils who fail.

Overall, the expert panel assesses that the levels of the test sets from 2008 for both HTX and STX are sufficiently high, yet the HTX test set is more ambitious than the corresponding STX set. The formulae the pupils are supposed to know in the HTX set are generally more complicated than in the STX set. One example of the high level in the HTX test set 2008 is task 3 about the chimney, which requires knowledge of rotation of rigid bodies, which in turn, according to the panel members' experience, pupils consider difficult. In this context the panel finds it important that the pupils' knowledge of fundamental Physics laws should be tested in the examination with an adequate progression. Therefore, the set could have included one more basic and not so demanding question within the problem. Another example that illustrates the difference in the level of difficulty in the test sets between the programmes appeared from comparison of task 2 in the STX test set, "A trip in an elevator", which includes data showing a linear relationship between two variables, and task 2 in the HTX test set which includes more variables displaying a non-linear relationship.

The expert panel assesses that the level in the HTX test set is generally very high, and the grade distribution confirms that the set was difficult; 8%[15] of the pupils obtained a high grade (10 or 12) in 2008 which is substantially lower than the average of 22% for the three preceding years before the reform. Moreover, a large proportion of the pupils (18%) failed the exam (below grade 2), which is slightly higher than the average of 15% for the three preceding years. These numbers fall short of the objective of the ECTS-standardisation[16]. Although, the panel recognises that structural matters, i.e. the introduction of a new grade-scale[17], could have affected the grading, the distribution of grades does give an indication that the level in the test set in 2008 might have been too ambitious. In comparison, the HTX test set from 2007, which was the last test set before the reform, is according to the panel easier than the 2008 set, yet the level is still adequate.

The STX test sets show a less significant increase in the level of difficulty from the former test sets to the present. However, the STX test set from 2008 includes elements that could not have been part of test sets prior to the reform, e.g. tasks where the pupils have to make assumptions themselves.

Generally, the expert panel assesses that the level of the STX test set from 2008 is reasonable. The grades of 2008 reflect that the STX pupils generally did better than the HTX pupils. In STX, 30%[18] of the pupils obtained a high grade, which is somewhat higher than the average of 25% for the three years preceding the reform and substantially higher than in HTX. However, 14% of the pupils in STX failed the exam in 2008, which is comparable to the average of 12% for the three preceding years and somewhat lower than the 18% for HTX.

[15] Disregarding the proportion of pupils who failed the examination, this is equivalent to approximately 10%.

[16] It should be mentioned that grades for written examinations in Danish upper secondary education generally do not comply with the objective of the ECTS-standardisation, and that written exam grades are generally significantly lower than oral grades.

[17] Furthermore, there has been a structural change regarding which pupils are to take the written examination. If a pupil has more than the normally required five subjects at level A, the pupil is still only required to take written examinations in five subjects at level A. It will then be random selection between the level A subjects that are contained in the specialised study package or are electives. This structural change might have influenced the grades.

[18] The equivalent of approximately 35% if the proportion of pupils who failed the examination is disregarded.

Examinations – key findings:

- The expert panel considers the oral examinations with their enhanced focus on evaluating pupils' competences within the planning, carrying out and application of experiments to be a strength of the Danish system. However, the value of the long duration of the exams, including preparation time might be questioned.

- The expert panel assesses that the open-book examination at level A makes room for a creative approach to the Physics tasks. This is especially prominent in the HTX test set that requires the use of a large dataset. However, the panel is concerned that a completely open book exam will not test whether the pupils have acquired sufficient basic knowledge.

- The demand for making assumptions, which is particularly prominent in the STX test set, and the increased use of context description in the test sets in both HTX and STX reflect the competences emphasised in the curricula. On the one hand, the expert panel assesses that making assumptions and finding useful information in the text are relevant competences to evaluate. On the other hand, the panel notes that a larger amount of text can be an obstacle for poor readers, and assesses that not all the text provided in the test sets is relevant to the tasks.

- The level in the test set for STX is adequate from the expert panel's point of view, and compares well internationally. The expert panel assesses that the HTX test set from 2008 was overly ambitious, and only a small proportion of pupils obtained a high grade in HTX compared to STX. A substantial proportion (14-18%) of the pupils did not pass the exam in both programmes.

Appendix A

The expert panel

Associate Professor, Carl Angell, University of Oslo. Carl Angell is currently head of the physics education research group within the Department of Physics, Oslo University, and before that taught physics in Norwegian upper secondary education. Carl Angell's research interest is Physics education in a broad sense, and includes several projects at upper secondary level concerned with, among other topics, the implementation of new elements in the Norwegian physics curriculum and the perception of Physics as a subject in physics education in Norway. Furthermore, he is currently involved in the ongoing TIMSS[19] advanced study, which assesses the achievement of pupils in their final year of upper secondary education in Physics at a high level.

Professor, Brian Bech Nielsen, University of Aarhus. Brian Bech Nielsen is Professor in the Department of Physics and Astronomy, University of Aarhus, where he is also Deputy Director of the interdisciplinary Nanoscience Center (iNANO). In his work, he has collaborated with experimental and theoretical groups from universities in various countries, including the UK, USA, Germany, Japan and Portugal, and he chairs the International Steering Committee for the International Conference on Defects in Semiconductors (ICDS). He has been responsible for a number of courses for graduate and undergraduate students in different subjects, ranging from Solid State Physics and Semiconductor Physics to Statistical Physics, Classical Mechanics, and Quantum Mechanics. In addition, he has given a number of lectures for teachers and pupils in upper secondary school.

Retired Senior Lecturer, Hendrik Ferdinande, Ghent University. Hendrik Ferdinande retired from *Universiteit Gent* in 2005, where he since 1991 had been a Lecturer and Senior Lecturer in Nuclear Physics in the Faculty of Sciences and the Faculty of Applied Sciences. He has been active as an expert in the field of Physics and as a member of the Management Committee for the project *Tuning Educational Structures in Europe*. In this connection, he has contributed to initiatives in Russia, Latin America (Peru) and Georgia. From 1996 till 2003, he was chairman of the SOCRATES Thematic Network Project EUPEN (*European Physics Education Network*), linking more than 150 physics departments from around 30 European countries, and has co-ordinated a three-year SOCRATES Thematic Network Project (2005/2008) called STEPS[20]. Since 2007 he has worked for the Academic Evaluation Centre of DAAD in Beijing, screening Chinese students planning to study in Germany or Belgium.

[19] *Trends in International Mathematics and Science Study*

[20] *Stakeholders Tune European Physics Studies*

Appendix B

Key persons interviewed

Subject Advisor for Physics in HTX, Peter Snoer Jensen, the Danish Ministry of Education. Additionally, Peter Snoer Jensen is a Senior Lecturer at *Roskilde Tekniske Skole* (HTX).

Subject Advisor for Physics in STX, Martin Schmidt, the Danish Ministry of Education. Additionally, Martin Schmidt is a Senior Lecturer at Egedal Gymnasium (STX) and HF.

Member of the exam commission for HTX, Anders Bjarklev. Anders Bjarklev is a Professor at DTU, the Technical University of Denmark, where he is also a Director of the Department of Photonics.

Member of the exam commission for STX, Jette Rygaard Poulsen. Jette Rygaard Poulsen is a Senior Lecturer at *Hasseris Gymnasium* (STX).

Chairman of the Physics Association in STX, Martin Kaihøj. Additionally, Martin Kaihøj is a Senior Lecturer at *Herlev Gymnasium* (STX).

Appendix C

Current HTX curriculum - Physics A

1. Identity and purpose

1.1 Identity

As a subject, physics is a study of mankind's attempts, through hypotheses, experiments and observations, to achieve a structured understanding of the world. As a subject, physics is both easy to relate to and practical, plus it involves our own experiences with physical phenomena. The subject is both experimental and theoretical and it places an emphasis on models, concepts and methods. The language and concepts of physics will be worked with. Physics contributes to the description, understanding and discussion of social and technological relationships and to the development of scientific and technological skills by putting topics into perspective from the point of view of the history of science and technology. Physics also gives an understanding of scientific methodology and its importance in influencing our perception of the world and its cultures.

1.2 Purpose

Physics contributes to the overall aim of the htx education because it requires the pupil to use scientific concepts and methods to solve both practical and theoretical problems.

Physics provides a base out from which the pupil can work with scientific methodology, learn to carry out project based tasks, work with experimental topics, with the theories of physics as well as with models and practical problems in workshops and laboratories. Via their physics classes, the pupils will build up a genuine level of skill in the subject, comparable to the highest level of senior high school and they will become capable of combining theoretical knowledge with experiments and using descriptive models in technological and technical areas. Physics will also strengthen the interactions between the pupil's chosen subjects by utilising knowledge gained in other subjects in specific projects and topics.

Physics will contribute to the pupil's understanding of a range of scientifically based questions, both general, technological and social, as well as to the pupil's study skills within the fields of science, technology and technical subjects.

2. Subject aims and content

2.1 Subject aims

The pupil should be capable of:

- analysing and assessing physical, technical and technological problems based upon the concept of models and on the basis of a chosen model give an account of its use, hereunder its use within a technical and technological field
- analysing problems, setting up a model to solve the problem, planning and carrying out physical experiments, documenting and communicating the resulting knowledge and the experimental work; as well as carrying out large experiments, where measuring, calculating and assessment are required.
- tackling new areas of physics and showing an understanding of scientific methodology in a wider context, giving an account of the areas where scientific methodology can be used and putting their knowledge of physics into a wider perspective via working with their own areas of interest

- having an insight into the fundamental laws of physics and using these in connection with their experimental work and when solving theoretical, technological and technical problems.
- explaining physical phenomena and putting certain areas of physics in an historical and technological perspective.

2.2 Core Material

The core material includes:

- the fundamental laws of kinematics and dynamics, Newton's laws, energy and work
- forces with different forms of movement in one and two dimensions
- circular motion, gravitational forces and the concept of energy
- momentum, conservation of momentum, collisions, angular momentum, moment of inertia and torque, hereunder Steiner's theorem
- the connection between the different forms of energy in relation to the rotation of a rigid body
- pressure and buoyancy
- the concept of energy, energy transformation and the conservation of energy
- the concept of temperature, phases of matter, phase transition, the ideal gas law and the work done by a gas
- the first and second laws of thermodynamics
- thermodynamic cycles, hereunder energy conversion efficiency and coefficient of performance
- laws and concepts to the description and calculation of direct current circuits
- electromotive forces and voltage
- electrical and magnetic forces and fields, including their importance for their technological and technical use and the movement of charged particles
- induction and the production of alternating current with particular reference to energy supplies
- harmonic waves, the fundamental concepts of wave theory, refraction and interference
- wave phenomena and simple optical refraction phenomena

2.3 Extension Material

Pupils will not be able to fulfil the subject aims by studying the core material alone. The extension material should account for approx. 35% of the lessons and contain at least two elective topics.

Whilst working with the extension material, the pupils should be able to put their insights into physics into a wider perspective and also work with their own areas of interest. Current technological topics will be included in the extension material along with a discussion of said topics quantitatively, qualitatively and from a social perspective.

3. Organisation

3.1 Pedagogic Principles

The physics teaching should, at the start, be based upon the level of knowledge that the pupil will be expected to have from primary and lower secondary school and should be carried out with an emphasis being placed on inductive, big picture teaching. The pupil should have the opportunity to draw their own conclusions, set their knowledge in a wider context and consider the technical and technological uses of physics theories, concepts and methods.

The teaching should be based upon the pupil's everyday experiences and involve topics from everyday technology. The teaching should mostly be carried out via topic based teaching and larger projects, where the pupil's curiosity, openness and investigative attitude should be encouraged. There should be a progression in the pupil's study, analytical and learning skills throughout the course of the teaching.

3.2 Learning Formats

Teaching should be organised such that it switches between theory and experiments. In physics an emphasis will be placed on the pupil's independent experimental work, which should be integrated throughout the course of the teaching. From the start, the pupil will be supported such that they become increasingly able to independently formulate, investigate and explain/describe physics' problems. The teaching should be organised such that it involves different models, descriptions and learning formats that are suitable for solving different types of questions. In addition, the pupil should compare the results from research or from industry with their own experimental results and communicate the results of this comparison both orally and in written form.

A major part of the extension material should be covered via the pupil's work with two elective topics and an independent project. The two elective topics and the topic of the independent project must be from different areas of physics.

The independent project should be based around a physical, technical or technological problem. The problem is chosen by the pupil themselves and is investigated via experimental work and study of the related theory. The results of the independent project should be presented in a project report.

The work with the two elective topics should be organised such that the pupil has an opportunity to go in-depth with a limited area of each of the two topics. Part of one of the two elective topics should be placed in study area part 2.

In conjunction with an interdisciplinary project in study area part 2, the pupil will carry out a small project, where their experimental work should illustrate results from the worlds of research or industry. This project should be presented via an oral presentation.

Documentation in the form of reports, journals, articles and IT-presentations should be generated and should, as a whole, cover the core material and the two elective topics. In addition, the pupil should hand in answers to written questions that are equivalent to those used in the written examination.

When the school chooses the oral examination b), 12 experiments from within the core material should be selected for use in the oral examination.

3.3 IT

In physics IT should be used in connection with data collation and the processing of measurements, simulations and visualisations so the pupil has the opportunity to try different models and thereby develops a background on which they can base their interpretations of experimental results.

IT-tools should be used to present investigations and results. The use of IT to search for information should be part of the entire course and used especially in connection with projects and the elective topics.

3.4 Interactions with other subjects

Physics is covered by the general requirements for interactions between subjects, whereby elements from other subjects are used in physics, especially elements from the other scientific subjects the pupil is studying. In addition to this there should be a specific interdisciplinary involvement with one of the following subjects: technology, a scientific subject, mathematics or sociology in conjunction with a project or topic within the physics course.

If the pupil, along with physics, is also studying a humanistic or social subject, a joint project must be planned where the technical, technological or social angle is dealt with.

If physics is an elective subject, the pupil's knowledge and skills from other subjects should be used in the physics course so that they contribute to putting physics' related topics into a wider perspective and to illustrating the technical and technological importance of the subject.

4. Assessment

4.1 Continuous assessment

An emphasis is placed on a thorough evaluation of the pupil's documentation for their experimental work, theory, elective topics and project work, so the pupil can assess what they have gained from the work and improve their level of attainment.

4.2 Examination types

A written and oral examination will be held.

Written examination

The written examination takes the form of a centrally generated set of questions, where IT will be part of the task. The questions will be based upon the core material given in paragraph 2.2. The examination lasts 5 hours.

Oral examination

The school chooses one of the two examination types given below for each individual class.

a) An oral examination based on experiments carried out as part of the preparation for the examination and either the examinee's own independent project or one of the two elective topics. 30 minutes are allotted for the examination. The pupil has 24 hours to prepare for the examination, within which the examinees, in groups of up to 4 persons, carry out one or more self selected experiments that illustrate a problem within a field selected by drawing lots. The themes should, when taken all together, cover the core material. At the same time it is decided, also by drawing lots, where the examinee will be examined on their own independent project or in one of the two elective topics. The experiments, as a whole, may only take a maximum of 6 hours to carry out. A description of the independent projects, the elective topics and the themes for the experiments will be sent to the external examiner prior to the examination being held. The examinee may only bring their independent project, documentation from the given elective topic and notes from this or the experiments carried out during the preparation period into the examination.

The examination will be centred on the examinee's presentation of their independent project or selected elective topic with an emphasis on the related theory. The examination will be supplemented with one or more questions from the internal examiner. The examinee will, after this, have to give an account of the experiments carried out in the preparation period and justify the choice of these in relation to the topic they were given. The examination will end as a conversation where the pupil can elaborate on their answers, including knowledge from areas of either the core material or the extension material.

b) Each examinee will draw lots to decide whether the examination will be based upon their independent project or one of the two elective topics. In addition, the examinee will choose, without seeing the questions, a question that is centred upon one of the 12 chosen experiments, which, as a group, cover the majority of the core material. A description of the independent projects, the elective topics and the selected experiments will be sent to the external examiner prior to the examination being held. The examinee will be given ca. 30 minutes preparation time, where all necessary equipment and written material from the physics course may be used. 30 minutes is allotted for the actual examination. The examinee may only bring their independent project or documents from the selected elective topic plus notes concerning the experiment they chose and any notes from their preparation time into the actual examination. The examination will be centred around the examinee's presentation of their independent project or the elective topic, with an emphasis being placed on the relevant theory. The examination will also contain one or more prepared questions from the internal examiner. The examinee will hereafter answer the question they selected. The final part of the examination takes the form of a discussion, which can cover topics from the entire range of core and extension material in the subject.

4.3 Assessment Criteria

The assessment of the pupil is an evaluation of to what extent their presentation lives up to the aims for the subject, c.f. paragraph 2.1.

In the *written examination*, an emphasis is placed on:

- the examinee's ability to analysis a problem, use a relevant model and justify their choice of methods
- the examinee's ability to evaluate the use of theories and models within the fields of technical work and technology
- the examinee's knowledge within the fields of wave theory, mechanics, thermodynamics, electrics and electromagnetism
- whether the examinee's thought processes can be seen clearly from their answer – symbol and formula rearrangement, intermediate calculations and the units given should be included in the pupil's answer
- the examinee's ability to use a scientific approach and methodology, their ability to use models, interpret experimental results and evaluate and analyse an experimental process, along with their ability to assess the technological conditions under which the experiment took place.

In the *oral examination*, an emphasis is placed on:

- the examinee's understanding of concepts and principles from the field of physics, their ability to organise their answer to the examination question and their understanding of the experimental work, including the laws of physics and their use, plus the concept of models
- the examinee's ability to work using a scientific approach and methodology and their ability to plan and carry out experiments.
- the examinee's ability to put their insights into physics in a wider perspective, based upon their work in their independent project or the elective topics
- the examinee's ability to use a scientific approach and methodology, their ability to use models, interpret experimental results and evaluate and analyse an experimental process, along with their ability to assess the technological conditions under which the experiment took place.

In both the written and oral examination, a grade is awarded based on an assessment of the examinee's overall performance in the examination.

Appendix D

Current HTX curriculum - Physics B

1. Identity and purpose

1.1 Identity

As a subject, physics is a study of mankind's attempts, through hypotheses, experiments and observations, to achieve a structured understanding of the world. As a subject, physics is both easy to relate to and practical, plus it involves our own experiences with physical phenomena. The subject is both experimental and theoretical and it places an includes models, concepts and methods.

The language and concepts of physics will be worked with. Physics contributes to the description, understanding and discussion of social and technological relationships and to the development of scientific and technological skills by putting topics into perspective from the point of view of the history of science and technology. Physics also gives an understanding of scientific methodology and its importance in influencing our perception of the world and its cultures.

1.2 Purpose

Physics contributes to the overall aim of the htx education because it requires the pupil to use scientific concepts and methods to solve both practical and theoretical problems.

Physics provides a base out from which the pupil can work with scientific methodology, learn to carry out project based tasks, work with experimental topics, with the theories of physics as well as with models and practical problems in workshops and laboratories.

Physics will enable the pupils to combine theoretical knowledge with experiments and use model based descriptions in technical and technological fields of study. Physics will also strengthen the interactions between the pupil's chosen subjects by utilising knowledge gained in other subjects in specific projects and topics.

Physics will contribute to the pupil's understanding of a range of scientifically based questions, both general, technological and social, as well as to the pupil's study skills within the fields of science, technology and technical subjects.

2. Subject aims and content

2.1 Subject aims

The pupil should be capable of:

- giving an account of physical, technical and technological problems and for the use of physical concepts and models in realistic conditions, hereunder uses in industry or the pupil's everyday life
- planning and carrying out simple physical experiments and analysing simple physical problems, - - setting up models to solve said problems as well as carrying out larger experiments, where measuring, calculating and assessment are required and then documenting and communicating the knowledge they have gained and the experimental work they carried out.
- giving an account of the areas where a scientific approach and methodology is used
- giving an account of physical phenomena and putting certain areas of physics in an historical and technological perspective

- using the basic laws of physics in connection with their experimental work and in solving simple theoretical problems.

2.2 Core Material

The core material includes:

- the fundamental laws of kinematics and dynamics, Newton's laws, energy and work
- forces with different forms of simple movement in one and two dimensions
- pressure and buoyancy
- the concept of energy, energy transformation and the connection between work, energy and the conservation of energy
- the concept of temperature, states of matter, phase transition, the ideal gas law and the work done by a gas
- laws and concepts for the description and calculation of simple direct current circuits
- electromotive force and voltage
- production of alternating current, with particular reference to energy supplies
- law of refraction and optical refraction phenomena

2.3 Extension Material

Pupils will not be able to fulfil the subject specific aims by studying the core material alone. The extension material should account for approx. 20% of the lessons and should contribute to putting the subject into a wider perspective and expand on areas from the core material and from the pupil's own areas of interest.

Current technological topics will be included in the extension material along with a discussion of said topics quantitatively, qualitatively and from a social perspective.

3. Organisation

3.1 Pedagogic Principles

The physics teaching should, at the start, be based upon the level of knowledge that the pupil will be expected to have from primary and lower secondary school and should be carried out with an emphasis being placed on inductive, big picture teaching. The pupil should set have the opportunity to put their knowledge in a wider context.

The teaching should be based upon the pupil's everyday experiences and involve topics from everyday technology. The teaching should mostly be carried out via topic based teaching and larger projects, where the pupil's curiosity, openness and investigative attitude should be encouraged.

3.2 Learning Formats

Teaching should be organised such that it is centred on the pupil's everyday life and experiences with physical phenomena. The teaching should be planned so that it switches between theory and experiments. In physics an emphasis will be placed on the pupil's independent experimental work, which should be integrated throughout the course of the teaching.

From the start the pupil will be supported such that they become increasingly able to independently formulate, investigate and explain/describe physics' problems.

The teaching should be organised such that it involves different models, descriptions and learning forms that are suitable for solving different types of questions.

In addition, the pupil should collect results from a piece of experimental work and compare them with investigations from the real world and communicate the results of this comparison both orally and in written form.

A major part of the extension material should be covered via the pupil's work with an independent project that is based around a physical, technical or technological problem. The problem is chosen by the pupil themselves and is investigated via experimental work and study of the relevant theory. The results of the independent project should be presented in a project report.

Documentation in the form of reports, journals, articles and IT-presentations should be generated and should, as a whole, cover the core material.

3.3 IT

In physics IT should be used in connection with data collation and processing of measurements, simulations and visualisations so the pupil has the opportunity to try different models and thereby develops a background on which they can base their interpretations of experimental results.

IT-tools should be used to present investigations and results. The use of IT to search for information should be part of the entire course and used especially in connection with projects and topic based work.

3.4 Interactions with other subjects

Physics is covered by the general requirements for interactions between subjects, whereby elements from other subjects are used in physics, especially elements from the other scientific subjects the pupil is studying. In addition to this there should be a specific interdisciplinary involvement with one of the following subjects: technology, a scientific subject, mathematics or sociology in conjunction with a project or topic within the physics course.

4. Assessment

4.1 Continuous assessment

An emphasis is placed on a thorough evaluation of the pupil's documentation for their experimental work, theory, topics and project work, so the pupil can assess what they have gained from the work and improve their level of attainment. Written and oral assessments of the pupil's level of attainment will be carried out.

4.2 Examination types

An oral examination will be held that will be centred upon the examinee's independent project, c.f. paragraph 3.2 and the experimental work carried out as part of the preparation for the examination. 30 minutes is allotted for the examination. The pupil has 24 hours to prepare for the examination, within which the examinees, in groups of up to 4 persons, carry out one or more self-selected experiments that illustrate a problem within a field selected by drawing lots. The fields should, when taken all together, cover the core and extension material. The experiments, as a whole, may only take a maximum of 6 hours to carry out. A description of the independent projects and the themes for the experiments will be sent to the external examiner prior to the examination being held. The examinee may only bring their independent project and notes from this or the experiments carried out during the preparation period into the examination.

The examination will be centred on the examinee's presentation of their independent project with an emphasis on the related theory. This part of the examination will be supplemented with one or more questions from the internal examiner. The examinee will, after this, have to give an account of the experiments carried out in the preparation period and justify the choice of these in relation to the topic they were given. The examination will end as a conversation where topics from the subject's core an extension material can be included.

4.3 Assessment Criteria

The assessment of the pupil is an evaluation of to what extent their presentation lives up to the aims for the subject, c.f. paragraph 2.1.

An emphasis is placed on:

- the examinee's ability to use a scientific approach , to plan and carry out simple scientific experiments and to give an account of the theory behind the experiment
- the examinee's ability to work using scientific methodology and to give an account of physical, technical and technological problems
- the examinee's ability to put their knowledge of physics into a wider perspective, as shown by their independent project and in the experiments carried out in the examination preparation time

- the examinee's understanding of concepts and principles from the field of physics and their understanding of the experimental work, including the laws of physics and their use

A grade is awarded based on an assessment of the examinee's overall performance in the examination.

Appendix E

Current STX curriculum – Physics A

1 Identity and purpose

1.1 Identity
The scientific subject of physics is concerned with mankind's attempts to develop general descriptions, interpretations and explanations of phenomena and processes in both nature and technology. Through an interaction between experiments and theories, a theoretically substantiated scientific insight will be developed, which can stimulate curiosity and creativity. At the same time, this insight will give a background from which a pupil can understand and discuss scientifically and technologically based arguments concerning questions of general human or social interest.

1.2 Purpose
Physics at the A level gives pupils a familiarity with important scientific methods and points of view, which, along with knowledge of physical phenomena and concepts, opens up for a scientific interpretation of the world. The pupils will be introduced to examples of current technical or scientific problems within the fields of science, development and production, where physics plays an important role in the problem's solution. Through their work with experiments and theoretical models, the pupils will gain knowledge of how physics models are set up and used as a means to qualitatively and quantitatively explain phenomena and processes. The pupils will work with texts that have a technical/scientific content and reflect upon the content and argumentation whilst at the same time gaining a broader perspective of the subject. The physics problems should also give the pupils an insight in to the physical and technological aspects of sustainable development.

2. Subject aims and content

2.1 Subject aims
The pupil should be capable of:

- knowing, setting up and using a wide selection of models to qualitatively and quantitatively explain physical phenomena, as well as discussing in which areas the model is valid
- analysing a physics problem using different representations of the data and formulate a solution for the problem using a suitable model
- planning, describing and carrying out physics experiments in order to investigate an open ended problem
- dealing with experimental data with the intention of discussing the mathematical connection between different physical quantities
- putting the contribution of physics to our understanding of natural phenomena, as well as technological and social development, into perspective via examples and in interaction with other subjects
- reading documents from the media and identifying the scientific elements and thereafter assessing the scientific validity of the arguments presented
- presenting a topic containing physics material to a chosen target audience

2.2 Core material

The core material is:

Physics' contribution to the scientific world view
- a basic outline of the current description of the universe and its development with a focus on the cosmological principle and the expansion of the universe, including the redshift of the electromagnetic spectrum
- the Earth as a planet in the Solar system as the explanation for easily observed natural phenomena
- nature's smallest building blocks, including the use of atoms as the basis for explaining macroscopic qualities during the formation of substances and elements

Energy
- work, energy and energy transformation as well as power and efficiency
- inner energy and energy conditions during temperature and phase transitions
- equivalency between mass and energy

Electrical circuits
- simple electrical circuits with steady current, described through the use of current intensity, voltage drop, resistance and energy transformation

Waves
- basic qualities: wavelength, frequency, phase velocity and interference
- light and sound as examples of waves
- the electromagnetic spectrum

Quantum Physics
- atoms and the make-up of the atomic nucleus
- the energy and momentum of photons and the wave-particle duality
- atomic system's emissions and the absorption of radiation, spectra
- radioactivity, including types of decay, total activity and exponential decay

Mechanics
- movements in one and two dimensions, including projectile motions and circular rotation
- law of conservation of momentum including elastic and inelastic collisions
- the concept of force and Newton's laws, including pressure, lift and friction
- the laws of gravity and movement around a central object
- force and energy condition in relation to harmonic oscillation
- mechanical energy in a uniform gravity field and for the gravitational field around a central object

Physics in the 21st century
- a subject which will be announced each year before the start of the final year

2.3 Extension material

Pupils will not be able to fulfil the subject aims by studying the core material alone. The extension material should account for 30% of the teaching given, and should be chosen so that it accomplishes the overall aims for the subject as well as the more academic aims. Current or socially relevant problems, including the highlighting of physical or technological aspects of sustainable development, should be included in the extension material.

3. Organisation

3.1 Pedagogic principles

When organising the teaching and selecting the material that the pupils will work with an emphasis should be placed upon giving the pupils an opportunity to experience the subject as relevant, meaningful and exciting.

Teaching should be organised such that it alternates between being systematically and thematically based, whilst at the same time ensuring that there is a progression in the demands placed upon the pupils' independence. In addition, the teaching should put physics into perspective by involving situations outside the subject. During the teaching, small projects should be planned that consider the following perspectives:

- physics illuminated through its interactions with history, religion or philosophy
- physics seen in relation to technological and social developments and the resulting social discussions
- physics in association with a paradigm shift in mankind's self-realisation

Part of the teaching should be organised such that, as much as practicalities allow, the class will come to work with actual challenges that are based upon a specific company or research institute.

When the teaching is being planned, an emphasis should be placed on coordinating the teaching with that of the mathematics course, so that the physics teaching builds upon realistic assumptions concerning the pupils' mathematical competency. Formal mathematical argumentation is less important than the use of mathematics in the study of physical systems. Use of the pupils' IT based mathematical tools, IT based simulations etc. should be included.

3.2 Learning formats

The teaching should be planned such that there is a variation and progression in the learning formats used, taking of course the aim of each individual project into account. The choice of learning format should give the pupils the courage to develop and realise their own ideas and to cooperate with others.

The pupils' experimental work should be an integrated part of the teaching and should ensure that the pupils are comfortable with experimental methods and the use of experimental equipment, including modern IT based equipment for data collection and processing. The experiments should be selected so that there is a progression in the demands placed upon the pupils' ability to work independently - from simply recording experimental data towards work with more complex relationships and on to independent experimental investigations. At least two longer projects, where the pupils work in small groups with an experiment they have chosen themselves, should be planned. The pupils' experimental work should account for at least 20% of the time allotted for teaching.

Oral presentations and written work are important parts of the subject. The written work includes:

- reporting and processing of experimental work
- communicating the insights they have gained in physics by means of texts, presentations and so forth
- solving physics' problems, including training in the use of different concepts, methods and models
- project reports

In physics the written work should be planned so that each piece has a clear aim and is part of a progression in the demands placed on the pupil to work independently. Work with problem solving should make the demands concerning the pupil's mastery of the subject aims in connection with the written examination in physics clear.

In connection with oral presentations, the pupils should have the opportunity to create presentations that can form the basis for independent pupil lectures on theoretical topics or experimental work.

3.3 IT
When the teaching is being planned, an emphasis should be placed on involving modern IT learning aids in connection with both the experimental work and with the pupils' work with theoretical physics and its presentation. The pupils should try to use IT based learning aids to both collect and process data. In addition the collection and working up of information about physics from the internet should be part of the teaching.

3.4 Interaction with other subjects
Physics is covered by the general demands concerning interaction between subjects and must be part of the general study preparation course and the basic scientific study package according to the regulations that govern these study packages.

When physics is part of the pupil's *chosen subject package*, a project should be planned in conjunction with the other subjects in the package that shows the strength of the interactions between the subjects and puts physics into a broader perspective. If physics is part of a subject package with mathematics, a special project should be planned, in which the two subjects cooperate on the treatment of models for actual physical problems, with an emphasis upon a discussion of the assumptions on which the models are based and on the reliability of the results obtained through the use of the models.

When physics is an *elective subject*, the teaching should be planned so that it emphasises involving the pupil's other subjects, so that they contribute to putting physics topics into a broader perspective and to illuminating the subject's general educational aspects.

4. Assessment

4.1 Continuous assessment
How much the pupil is gaining from the teaching should be assessed regularly, so there is a basis for guiding the individual pupil towards progress in reaching the aims for the subject and a basis for adjusting the teaching.

4.2 Examination forms
A centrally set written examination and an oral examination will be held.

The written examination
The written examination will consist of centrally set questions. The examination will last 5 hours. The physics on which the questions are based is described in the core material in paragraph 2.2, but other topics and problems can be included, as long as the basis for the question is described in the question text.

The oral examination
The examination is divided into two sections, with up to 10 examinees per day.

The first part of the examination is experimental, where the examinees work with a problem in the laboratory for 2 hours in groups of max. 3 examinees. During this part of the examination, the examinees may use experimental instructions, textbooks and similar items. The internal and external examiners will talk with the individual examinees about the specific experiment they are carrying out and the related theory.

The other part of the examination is individual and oral. This part of the examination lasts 24 minutes and 24 minutes is given for preparation. The examination question should be about a mostly theoretical physics topic and include an appendix that can be the basis for putting the topic in a broader perspective. The experimental and the theoretical sections of the examination should be combined so that they cover different topics. The examination should take the form of an academic discussion between the examinee and the internal examiner.

4.3 Assessment criteria
The assessment of the pupil's performance is an assessment of to what extent they have fulfilled the subject aims given in paragraph 2.1.

The written examination
In assessing the written examination, an emphasis placed on whether the pupil:
- masters a broad spectrum of concepts and models used in physics
- can analyse a physics problem, solve it by using a relevant model and communicate their analysis and results clearly and precisely
- can set up a model and discuss in what areas it is valid to use said model

A single grade is awarded based on an overall assessment of the pupil's performance

The oral examination
In the experimental part, an emphasis is placed on whether the pupil:
- can carry out the experimental work and treat and analyse the collected data
- In the oral part of the examination an emphasis is placed on whether the pupil, during the discussion, shows independent initiative and:
- has a solid knowledge of the concepts, models and methods used in physics and can use them as the basis for an academic analysis and an explanation of the argumentation used
- can reflect on the interaction between theory and experiment
- can put their insights into physics into a broader perspective

Each examinee is given an individual grade based on an overall assessment of the examination's experimental and oral sections.

Appendix F

Current STX curriculum – Physics B

1 Identity and purpose

1.1 Identity

The scientific subject of physics is concerned with mankind's attempts to develop general descriptions, interpretations and explanations of phenomena and processes in both nature and technology. Through an interaction between experiments and theories, a theoretically substantiated scientific insight will be developed, which can stimulate curiosity and creativity. At the same time, this insight will give a background from which a pupil can understand and discuss scientifically and technologically based arguments concerning questions of general human or social interest.

1.2 Purpose

Physics at the B level gives pupils a familiarity with important scientific methods and points of view, which, along with knowledge of physical phenomena and concepts, opens up for a scientific interpretation of the world. The pupils will be introduced to examples of current technical or scientific problems within the fields of science, development and production, where physics plays an important role in the problem's solution. Through their work with experiments and theoretical models, the pupils will gain knowledge of how physics models are set up and used as a means to qualitatively and quantitatively explain phenomena and processes. The pupils will work with texts that have a technical/scientific content and reflect upon the content and argumentation whilst at the same time gaining a broader perspective of the subject. The physics problems should also give the pupils an insight in to the physical and technological aspects of sustainable development.

2. Subject aims and content

2.1 Subject aims

The pupil should be capable of:

- knowing, setting up and using a wide selection of models to qualitatively and quantitatively explain physical phenomena
- undertaking calculations of physical quantities, based upon basic concepts and models
- planning, describing and carrying out an actual experiment based on a given problem and using the equipment provided, as well as presenting the results appropriately
- dealing with experimental data with the intention of discussing the mathematical connection between different physical quantities
- putting the contribution of physics to our understanding of natural phenomena, as well as technological and social development, into perspective via examples and in interaction with other subjects
- reading documents from the media and identifying the scientific elements and thereafter assessing the scientific validity of the arguments presented
- presenting a topic containing physics material to a chosen target audience

2.2 Core material

The core material is:

Physics' contribution to the scientific world view

- a basic outline of the current description of the universe and its development with a focus on the cosmological principle and the expansion of the universe, including the redshift of the electromagnetic spectrum
- the Earth as a planet in the Solar system as the explanation for easily observed natural phenomena
- nature's smallest building blocks, including the use of atoms as the basis for explaining macroscopic qualities during the formation of substances and elements

Energy

- work, energy and energy transformation as well as power and efficiency
- kinetic and potential energy in the gravity field near Earth
- inner energy and energy conditions during temperature and phase transitions
- equivalency between mass and energy

Electrical circuits

- simple electrical circuits with steady current, described through the use of current intensity, voltage drop, resistance and energy transformation

Waves

- basic qualities: wavelength, frequency, phase velocity and interference
- light and sound as examples of waves
- the electromagnetic spectrum

Quantum Physics

- atoms and the make-up of the atomic nucleus
- the energy and momentum of photons and the wave-particle duality
- radioactivity, including types of decay, total activity and exponential decay

Mechanics

- kinematic descriptions of movement in one dimension
- the concept of force, including gravitational force, pressure, lift
- Newton's laws, applied to movement in one dimension

2.3 Extension material

Pupils will not be able to fulfil the subject aims by studying the core material alone. The extension material should account for 25% of the teaching given, and should be chosen so that it accomplishes the overall aims for the subject as well as the more academic aims. Current or socially relevant problems, including the highlighting of physical or technological aspects of sustainable development, should be included in the extension material.

3. Organisation

3.1 Pedagogic principles

When organising the teaching and selecting the material that the pupils will work with an emphasis should be placed upon giving the pupils an opportunity to experience the subject as relevant, meaningful and exciting. Teaching should be organised such that it alternates between being systematically and thematically based, whilst at the same time ensuring that there is a progression in the demands placed upon the pupils' independence. In addition, the teaching should put physics into perspective by involving situations outside the subject. During the teaching, small projects should be planned that consider the following perspectives:

- physics illuminated through its interactions with history, religion or philosophy
- physics seen in relation to technological and social developments and the resulting social discussions

- physics in association with a paradigm shift in mankind's self-realisation
- Part of the teaching should be organised such that, as much as practicalities allow, the class will come to work with actual challenges that are based upon a specific company or research institute.

When the teaching is being planned, an emphasis should be placed on coordinating the teaching with that of the mathematics course, so that the physics teaching builds upon realistic assumptions concerning the pupils' mathematical competency and provides, where possible, relevant examples that can be used in the mathematics class. Formal mathematical argumentation is less important than the use of mathematics in the study of physical systems. Use of the pupils' IT based mathematical tools, IT based simulations etc. should be included.

3.2 Learning formats

The teaching should be planned such that there is a variation and progression in the learning formats used, taking of course the aim of each individual project into account. The choice of learning format should give the pupils the courage to develop and realise their own ideas and to cooperate with others.

The pupils' experimental work should be an integrated part of the teaching and should ensure that the pupils are comfortable with experimental methods and the use of experimental equipment, including modern IT based equipment for data collection and processing. The experiments should be selected so that there is a progression in the demands placed upon the pupils' ability to work independently - from simply recording experimental data towards work with more complex relationships and on to independent experimental investigations. At least one longer project, where the pupils work in small groups with an experiment they have chosen themselves, should be planned. The pupils' experimental work should account for at least 20% of the time allotted for teaching.

Oral presentations and written work are important parts of the subject. The written work includes:
- reporting and processing of experimental work
- communicating the insights they have gained in physics by means of texts, presentations and so forth
- solving physics' problems, including training in the use of different concepts, methods and models
- project reports

In physics the written work should be planned so that each piece has a clear aim and is part of a progression in the demands placed on the pupil to work independently. Work with problem solving should be planned so that it also shows progression. The pupils should be made familiar with the demands that are made in relation to answering the questions that are found in the written physics examination.

In connection with oral presentations, the pupils should have the opportunity to create presentations that can form the basis for independent pupil lectures on theoretical topics or experimental work.

3.3 IT

When the teaching is being planned, an emphasis should be placed on involving modern IT learning aids in connection with both the experimental work and with the pupils' work with theoretical physics and its presentation. The pupils should try to use IT based learning aids to both collect and process data. In addition the collection and working up of information about physics from the internet should be part of the teaching.

3.4 Interaction with other subjects

Physics is covered by the general demands concerning interaction between subjects and must be part of the general study preparation course and the basic scientific study package according to the regulations that govern these study packages.

When physics is part of the pupil's *chosen subject package*, a project should be planned in conjunction with the other subjects in the package that shows the strength of the interactions between the subjects and puts physics into a broader perspective. If physics is part of a subject package with mathematics, a special project should be planned, in which the two subjects cooperate on the treatment of models for actual physical problems, with an emphasis upon a discussion of the assumptions on which the models are based and on the reliability of the results obtained through the use of the models.

When physics is an *elective subject*, the teaching should be planned so that it emphasises involving the pupil's other subjects, so that they contribute to putting physics topics into a broader perspective and to illuminating the subject's general educational aspects.

4. Assessment

4.1 Continuous assessment

How much the pupil is gaining from the teaching should be assessed regularly, so there is a basis for guiding the individual pupil towards progress in reaching the aims for the subject and a basis for adjusting the teaching.

4.2 Examination forms

The examination is divided into two sections, with up to 10 examinees per day.
The first part of the examination is experimental, where the examinees work with a known problem in the laboratory for 1½ hours in groups of max. 3 examinees. During this part of the examination, the examinees may use experimental instructions, textbooks and similar items. The internal and external examiners will talk with the individual examinees about the specific experiment they are carrying out and the related theory.

The other part of the examination is individual and oral. This part of the examination lasts 24 minutes and 24 minutes is given for preparation. The examination question should be about a mostly theoretical physics topic and include an appendix that can be the basis for putting the topic in a broader perspective. The experimental and the theoretical sections of the examination should be combined so that they cover different topics. The examination should take the form of an academic discussion between the examinee and the internal examiner.

4.3 Assessment criteria

The assessment of the pupil's performance is an assessment of to what extent they have fulfilled the subject aims given in paragraph 2.1.

In the *experimental* part, an emphasis is placed on whether the pupil:

- can carry out the experimental work and treat and analyse the collected data
- In the oral part of the examination an emphasis is placed on whether the pupil, during the discussion, shows independent initiative and:
- has a solid knowledge of the concepts, models and methods used in physics and can use them as the basis for an academic analysis and an explanation of the argumentation used
- can reflect on the interaction between theory and experiment
- can put their insights into physics into a broader perspective
- Each examinee is given an individual grade based on an overall assessment of the examination's experimental and oral sections.