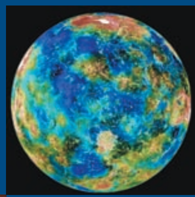
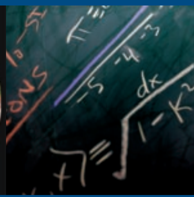



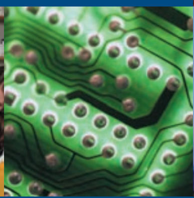


Physics – building a flourishing future

Report of the Inquiry into Undergraduate Physics

Institute of Physics

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Contents

A separate annex, *Statistics of Physics in UK Higher Education,* is available.

Executive Summary

- Physics education develops strong intellectual and practical skills, well matched to the evolving needs of employers.
- Physics provides the foundation for all of engineering and many scientific disciplines, including communications technologies, aerospace, the geosciences, biomedicine and the life sciences.
- Physics addresses profound questions about the universe and seeks to understand the complex physical and environmental systems in which we exist.

There are concerns, however, which are jeopardising the contribution that physics makes to wealth creation, innovation and economic growth:

The current MPhys[1] and BSc degrees produce high-quality mathematically-competent graduates who are eagerly sought by employers. The MPhys leads to highly skilled researchers needed by industry and academe. However, changes in the nature of mathematics courses at school level have led to **students being less proficient and confident in the mathematical skills** required by physics degree courses.

Over the past 15 years, numbers taking physics degrees have held approximately level (against increasing HE participation) with the proportion of women remaining around 20%. In England, physics has lost its status as the most popular science studied at A-level. Employer demands for scientists and engineers are not being met. **More needs to be done to increase the flow of physics graduates into research in industry and academe,** and to increase the number of people with the skills of a physics-based education for teaching, commerce, and the public sector.

A large proportion of 18-year-olds with good physics grades go on to study subjects such as IT, engineering and biomedical sciences. Many who are not attracted by heavily mathematically-based physics courses are seeking other degrees. There is, therefore, **an opportunity to develop courses that provide the intellectual education of physics, with its analytical, modelling and practical aspects, but in a broader context.**

There is a crisis in the teaching of physics in schools – two thirds of physics is taught to the under-16s by teachers without a physics degree. Only those with confidence and competence can teach their subject well, engaging and enthusing pupils and motivating them to pursue careers in science and engineering. **Unfortunately, teaching is not seen as an attractive career option for physics graduates, and the number entering is at an all-time low.**

The economics of university physics departments, including a chronic under-funding of laboratory infrastructure, has led to the loss of more than 10 departments in the past ten years. **Larger areas of population and industry now have no convenient access to a local university physics department offering teaching or research.** As the proportion of students living at home increases, as industry becomes more dependent upon high-technology knowledge and as the links between schools and universities become stronger, these regions will suffer from a lack of proximity to university physics.

[1] *'MPhys' is used to denote either an MSci in physics or an MPhys degree.*

Recommendations

An increasing number of young people must be enthused by physics. Physics is a unique training that provides a basis of key skills, develops innovative ways of tackling problems, addresses fundamental needs of industry and contributes to economic development.

- Government must invest more in promoting science and science-based careers, and ensure that the school physics curriculum is exciting and relevant to both boys and girls and taught by teachers with knowledge and experience in physics.
- The Institute of Physics must increase its efforts to interest young people in physics, and work with the Standing Conference of Physics Professors and others to increase variety in university physics provision.
- The Institute of Physics should establish a programme, working with others, actively to promote physics careers to women and to address the problems of enthusing girls to study physics.

The critical shortage of physics teachers in schools and colleges is the greatest threat to the future supply of skilled scientists and engineers. It is crucial that it is addressed at a national level.

- Parliament should investigate the crisis in teaching and address the five major deterrents – pay, conditions, status, workload and technical provision in schools.
- Government must accept and respond to market forces that dictate differential salaries for teachers in shortage subjects.
- Government should set targets for the proportion of science classes taught to the 14-19 age range by subject specialists and collaborate with educational and scientific bodies to implement policies designed to meet the new targets.
- University physics departments must increase their linkages to schools and teachers, offering support, advice and access to equipment – and must receive due credit for doing so. The Institute of Physics should support and encourage this.

The MPhys and BSc degrees must be maintained as the primary source of highly-qualified physicists for manufacturing and service industry, academe and research.

- University physics departments must consider re-balancing content, in order to strengthen skills in the use of mathematics for physics, to build transferable skills and to cater better for the changing knowledge base of new undergraduates, without losing the excitement of physics.
- University physics departments must become increasingly aware of the diverse routes now available to students to demonstrate their ability, at all stages of life. They must seek and admit the best possible candidates into physics degrees, whatever their background.
- The Institute of Physics should consider producing a series of mathematics modules to assist physics departments in addressing the mathematics needs of those studying degree programmes in physics.
- The Institute of Physics and the Standing Conference of Physics Professors must use their influence with government and pan-European educational bodies to ensure that the MPhys is accorded 'second cycle' status within negotiations dedicated to achieving European convergence in higher education.

There is a case for a New Degree drawing heavily upon physics – being more interdisciplinary in focus and accessible by undergraduates with more modest mathematical experience.

- The Institute of Physics, with others, should establish a working group:
  - to explore demand from potential students and employers;
  - to determine the best level for the 'New Degree' (e.g. a free-standing bachelors degree; associated bachelors and integrated masters degrees; or a foundation degree with a linked bachelors degree);

- to consider the funding of the degree and the types of institutional providers;
- to establish the range of material to be covered;
- to develop a launch strategy for the degree.

The funding of physics departments must be addressed, and the erosion of regional provision of physics courses halted.

- The Funding Bodies should monitor the ‘Price Groups’ allocated to laboratory sciences and ensure that they remain sufficient to sustain world-leading teaching quality.
- Universities must look to collaboration and sharing of resources to optimise the delivery of diverse and innovative physics courses.
- The Funding Bodies should ensure that all significant centres of population and industry have access to the people, teaching and research that come from physics departments.

1 Introduction

'Physics (including astronomy)[2] is an integral part of our culture, providing the foundations for many scientific disciplines including chemistry, biology, the geo-sciences and engineering. The increase in wealth, economic globalisation, living standards and the quality of life in the 20th century have been largely based on technological progress which in turn has relied heavily on innovative research in physics. These trends are anticipated to continue and, indeed, strengthen in the 21st Century.'

International Perceptions of UK Research in Physics and Astronomy, Report 2000[3]

In the ten years since the publication of the report entitled *The Future Pattern of Higher Education in Physics,* much has changed in British higher education. The binary divide between polytechnics and universities has been removed; a far larger fraction of school leavers now aspires to a university education; pressures for excellence in research and teaching have increased; integrated masters degrees have been introduced in science, mathematics and engineering; and funding pressures have led to the closure of several smaller physics departments. Following the publication in 1997 of the report of the National Inquiry into Higher Education ('The Dearing Report'), university tuition fees have been introduced and maintenance grants largely abolished.

Conscious of the many profound changes in the landscape of British undergraduate scientific education, the Council of the Institute in October 2000 requested that the President of the Institute establish a Panel of Inquiry. The Inquiry was tasked to explore and examine the provision of university physics courses in British universities, including four-year honours degrees, bachelors degrees, sub-degree qualifications, combined honours programmes and service teaching to other faculties and departments.[4]

The *Future Pattern* report retains much of its original relevance today and provides a serious and pertinent examination of the content and provision of physics honours degrees. Given the rigour and continued relevance of this previous exercise, the Panel determined that this latest Inquiry would concentrate on the wider role of physics in UK higher education.

The need to maintain and enhance the capabilities of the UK in world-leading science and technology remains as pressing today as it has ever been, and this report will consider such issues in depth. In addition, the report will explore ways in which physics and physicists can better serve the needs of all those with an interest in, and aptitude for, higher education in physics.

[2] *In this report 'physics' is used, unless otherwise specified, to span the full range of courses associated with the subject, including astronomy.*

[3] International Perceptions of UK Research in Physics and Astronomy *Panel Report 2000 sponsored by the Engineering and Physical Sciences Research Council, the Institute of Physics, the Particle Physics and Astronomy Research Council and the Royal Astronomical Society.*

[4] *See Appendix I,* Inquiry Membership, Terms of Reference and Methodology.

2 Demand

Physics is a broad scientific discipline ranging from the science of cosmology to the hands-on manipulation of matter at the atomic scale. There is a common theme running throughout the eclectic range of problems studied by the physics community, which may be summarised as a systematic and quantitative curiosity into why things are the way they are. More than anything else, physics is a framework for obtaining a predictive understanding of our world. Physicists are trained to solve problems using quantitative techniques.

Physics is a pillar of our scientific culture and its presence in our national life is of vital importance to the intellectual vigour of the United Kingdom. The need continually to enrich the UK's knowledge base leads to a demand for advanced scientific education.

Physics higher education continues to train and equip highly able students with the skills and competencies necessary for them to pursue fulfilling careers that contribute to the nation's wealth and health. The Inquiry Panel notes, and supports, the central theme of the 1997 National Committee of Inquiry into Higher Education (the 'Dearing Inquiry') – the widening of participation in higher education.

As part of the Inquiry, the Panel commissioned a Web-based survey of the attitudes of current and former undergraduates so that it might learn at first hand the issues facing physics students. The results of these consultations are reported in Appendix IV.[5] These consultation processes, together with discussions at the Inquiry's regional fora,[6] have confirmed that students on traditional physics degrees are to a large extent motivated to study the subject by an innate curiosity for the workings of nature. Physics students are conscious of the career value of training in physics, but above all it is students' curiosity and love for the subject that university physics departments must satisfy if the subject is to continue to appeal to young people.

[5] *The survey found that the most important factors motivating students were, with almost equal weight, fascination with the physical properties of matter and fascination with astronomy / space / science fiction. The next most popular motivation for students is reported as wanting to keep a wide range of options open. This motivation is, however, reported by only a fifth of the students citing 'fascination' as their main motivating factor. These findings were discussed in an article in the May 2001 issue of* Physics World *and community comment was sought on this, and other observations from the survey.*

[6] *See Appendix I,* Inquiry Membership, Terms of Reference and Methodology.

2.1 Physics – a toolkit for the modern world

'Physics is concerned with the observation, understanding and prediction of natural phenomena and the behaviour of man-made systems. It deals with profound questions about the nature of the universe and with some of the most important practical, environmental and technological issues of our time. Its scope is broad and involves mathematics and theory, experiment and observations, computing, technology, materials and information theory. Ideas and techniques from physics also drive developments in related disciplines, including chemistry, computing, engineering, materials science, mathematics, medicine and the life sciences, meteorology and statistics.'

Draft benchmark statement for physics degrees (2001), Quality Assurance Agency.

The 2000/2001 Foresight exercise highlights the numerous important contributions that will be required of physics in the next two decades.[7] In particular, physics and engineering have much to provide to those tasked with addressing public demands for improvements in energy storage and efficiency of use, public transport, crime prevention and the quality of life of older people.

Many of the new demands placed upon scientists and engineers are highly interdisciplinary. Problems ranging from climate change to drug delivery require increasingly flexible approaches to science and its application. Research physicists have much to contribute to multi-disciplinary teams addressing such problems. The growth of biochemistry at the interface of biology and chemistry emerged strongly in the years after World War II, driven by particular research interests and increasing industrial demands in pharmaceuticals. Similarly the fields of medical physics and biophysics have strengthened greatly in recent decades, with new physics-based technologies applied to medical diagnosis, therapy and problems in fundamental biology. Not to be overlooked is the interface between physics and chemistry. Physical chemistry is a well-established scientific area with a proud and lengthy history, but one which represents only part of the wider physics–chemistry interface. Research developments in this sector include nano-technology, energy generation and efficiency, atmospheric research, surface science, smart materials and novel plastics. Physics' role in interdisciplinary scientific higher education will be considered further in this report.

2.2 Physicists – delivering the future

Perhaps the greatest contribution that university physics departments make to UK national life is the annual production of trained physicists.

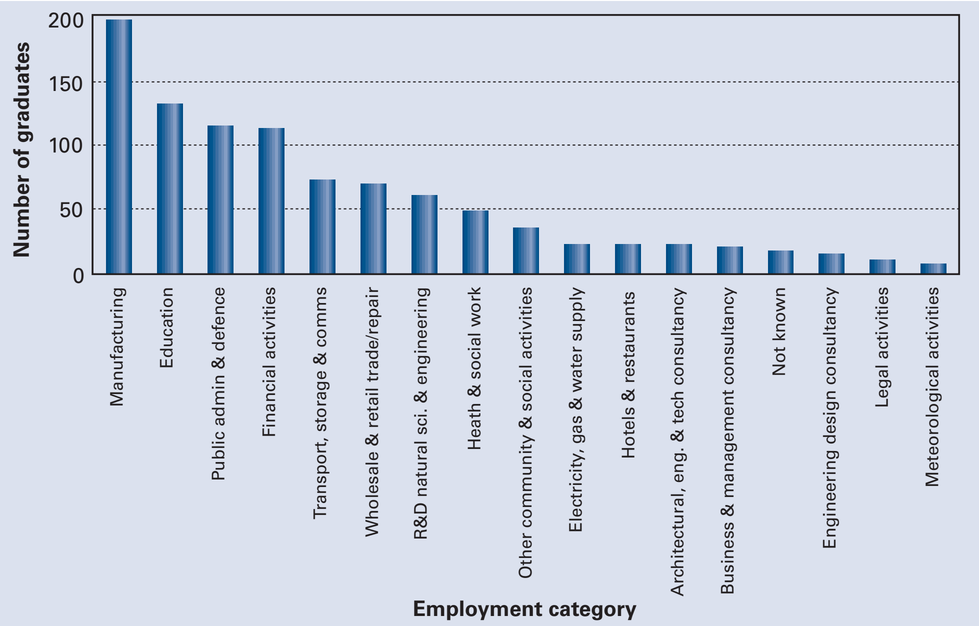
As figure 1 illustrates, the national demand for trained physicists extends far beyond the narrow community that will pursue a research career in physics. Physics higher education satisfies important national requirements for highly skilled people in many areas, including the information technology sector, financial analysis, engineering, environmental science, energy technology, intellectual property law and medical physics.

Secondary education in physics is of benefit to all careers and is an essential aspect of engineering, computing, medicine and the life sciences, among many other fields.

[7] Foresight for the 21st Century – *a forward look for physics, Institute of Physics, 2001.*

Figure 1

'First Destination Data' – major employment categories of UK students obtaining a physics qualification (undergraduate or postgraduate) at university in the academic year 1998/1999 (source: HESA).



2.3 Views of employers

Views of employers of physicists have been sought through questionnaires mailed to over 100 employers and through informal discussions with employers. In addition, account has been taken of other surveys of employers' requirements of graduate skills and an EPSRC survey of views of employers of physicists with postgraduate qualifications (generally PhD).[8] The following views have emerged.

As revealed by the Inquiry's surveys and consultation meetings, there is currently a high demand for good physics graduates, with some employers having difficulty recruiting. The Panel welcomes the inquiry into the supply of scientists and engineers set up by theTreasury ('The Roberts Inquiry') during the summer of 2001. Physicists find employment in a wide range of sectors, often far from what would conventionally be attributed to physics. What is frequently sought is a combination of good technical and analytical skills combined with good team-working and communications skills.

Employers value the following attributes of physics graduates:

- flexibility and versatility to tackle a wide range of technical and non-technical subjects;
- good analytical and problem-solving skills;
- good mathematical and IT skills;
- a good breadth of technical interest and ability;
- a good understanding of fundamentals from which to approach new situations where traditional approaches do not work;
- analytical problem-solving capabilities (in some sectors, including the financial sector, emphasis is put on the advantages of a research training in enhancing these skills);
- an ability to grasp concepts quickly and in a quantitative way (more important than knowledge of a particular specialism);
- an ability "to argue on one's feet".

[8] Employers' Views of Postgraduate Physicists, *Institute for Employment Studies report for the EPSRC, N. Jagger, S. Davis, D. Lain, E. Sinclair and T. Sinclair (February 2001).*

Employers would also like to see:

- improved social, interpersonal and team-working skills;
- better communication skills, particularly written skills ;
- a less academic and more pragmatic approach;
- improved business awareness;
- a greater awareness that not all problems can be solved by logic alone.

The general view is that after graduates have been with a company for a few years there is little to distinguish between graduates in physics, electrical engineering, other engineering, mathematics or (to a lesser extent) chemistry. The key issue for employers of physicists appears to be in combining the technical, analytical and problem-solving skills (in which physics and engineering graduates tend to be strong) with the 'softer' communication and team-working skills (in which they tend to be weaker). Whereas graduates were more frequently employed on the basis of their skills rather than specific knowledge, some employers regard PhDs as vocational and recruit on the basis of the particular specialism. Others anticipate having to train PhD graduates as they do those with first degrees, but appreciate the additional skills they have acquired through research. The research experience of the PhD provides recruits with a greater independence of vision. This important attribute is shared, albeit in a somewhat attenuated form, by MPhys graduates and is believed to arise as a consequence of the degree's research component.

There is concern among employers about the supply of physics and engineering graduates, starting with teaching in schools. In addition to the shortage of physics teachers, it is felt that science teaching is too passive, with too much passing on of knowledge without the opportunity to discuss and debate, that is available in other subjects, such as the humanities. Physics is regarded as a hard subject and it appears that some schools are reluctant to present pupils for physics. Perhaps this is because they perceive that some pupils could jeopardise their chances for a university place by getting a poorer A-level grade in physics than they would get in some other subjects. Schools may also be reluctant to enter students for physics A-levels because of a desire to maintain the school's high score in average A-level points. Concern has been expressed by employers that careers advice at schools does not emphasise the broad range of options available to students who pursue degrees in physics. In addition to the very strong national demand for physicists with the traditional skills of quantitative analysis, data handling and experimentation, employers are increasingly requiring scientists with interdisciplinary skills.

Increasingly, technically skilled graduates will be employed in sectors that previously have not recruited such employees. Such employees will include technical sales staff, technicians, communications and IT engineers, environmental monitors and regulatory officers.

2.4 Numbers studying science

Figure 2 illustrates student enrolments for science at A-level in England, Wales and Northern Ireland (EWNI). Physics has declined more in both absolute and percentage terms than any of the other subjects shown.

Figure 2

The total number of graded entries to A-level examinations in sciences and mathematics 1985–2000 (source: AQA). Note: Entry figures for mathematics include data for further mathematics, which is 7-8% of the total.

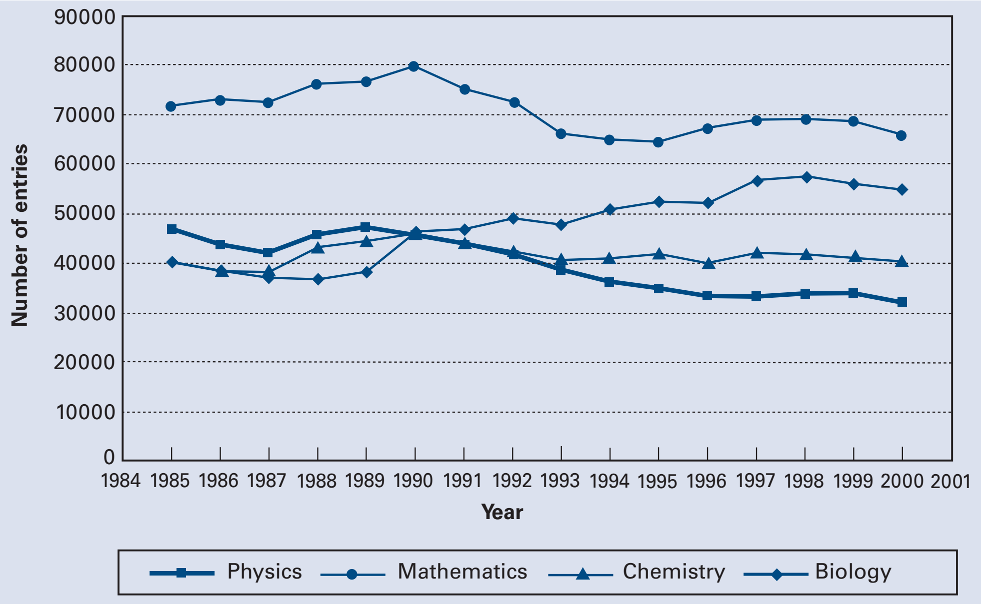
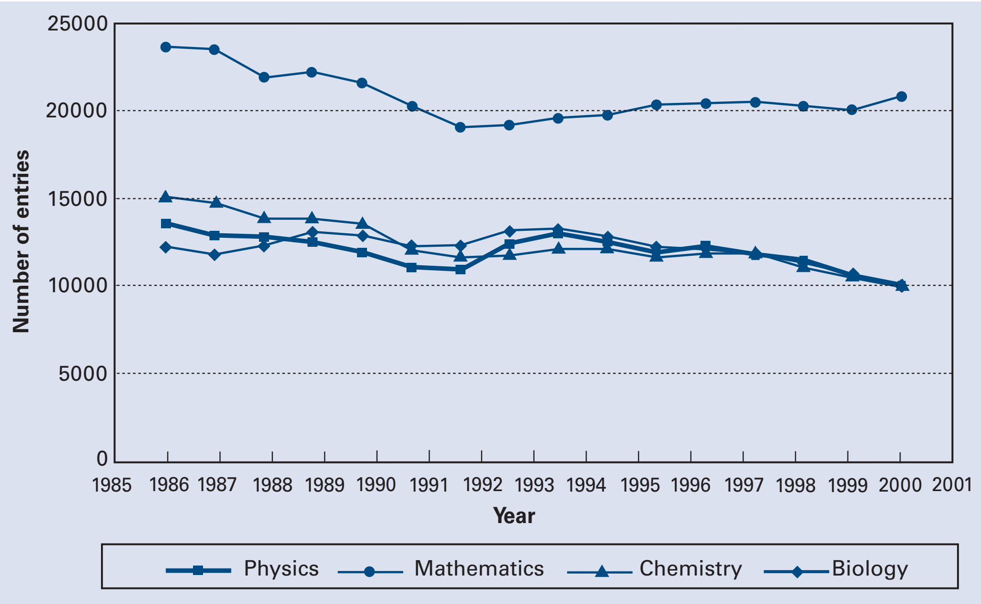


Figure 3

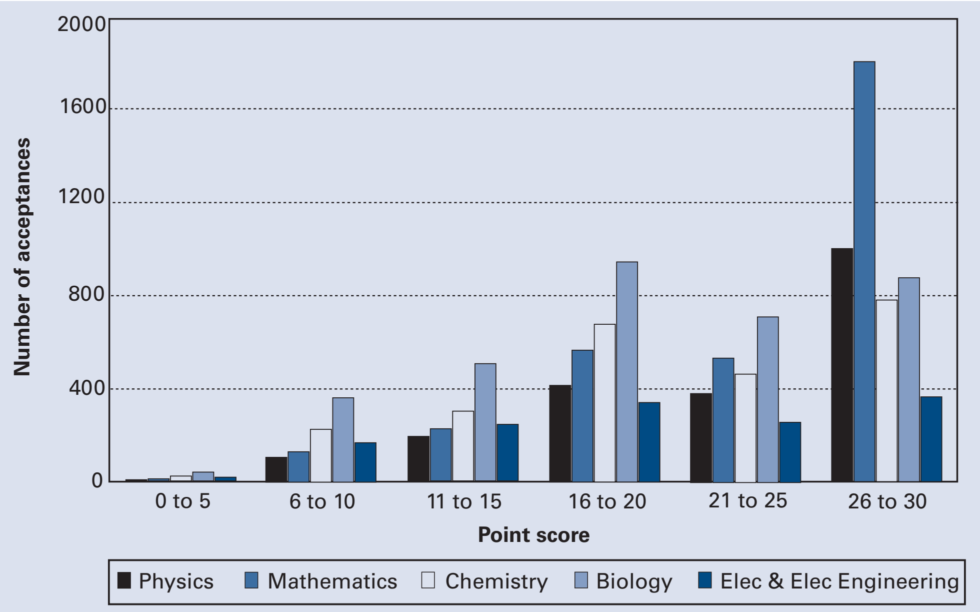
Scottish Higher examination entries in sciences and mathematics 1985–2000 (source: SQA). Note: Data for 2000 are provisional.



Physics students enter university with especially strong A-level points scores (EWNI). For instance, figure 4 shows that two thirds of physics degree students enrol with at least 21 points at A-level.

Figure 4

A-level point scores for home acceptances to first degrees in sciences, mathematics, and electrical and electronic engineering 2000 (source: UCAS).



The nature of the education system in Scotland, however, largely ensures that physics maintains parity of popularity with chemistry and biology. Science generally in Scotland is also showing signs of slow decline (see figure 3).

Figure 5

The total number of UK university first degree qualifications in sciences, mathematics, and electrical and electronic engineering 1986–2000 (source: USR 86–94 and HESA 95–00). Note: These data exclude degrees awarded by the CNAA to students at polytechnics. In 1993/1994 the binary divide was removed. The MSci / MPhys/MChem degrees were first introduced for physics and chemistry in 1996/1997.

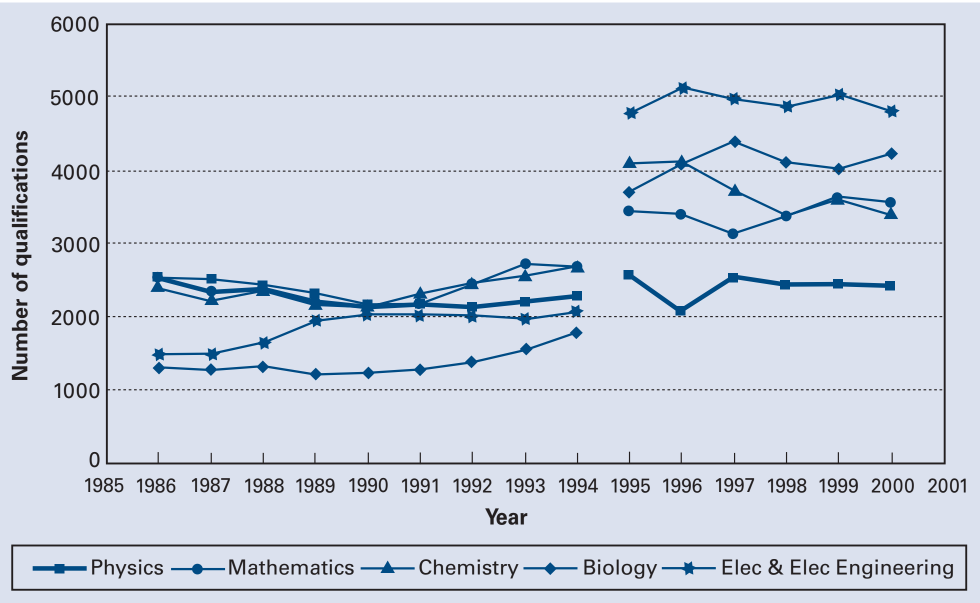


Figure 5 illustrates that for more than ten years the number of undergraduate students studying physics has remained approximately constant at 2,300.[9] Figure 5 reflects data for graduates from UK universities and, as such, does not include degrees from polytechnics awarded by the CNAA. Figure 5 shows, for physics, that the introduction of four-year MPhys degrees (mostly awarded for the first time in 1997) had more impact on university graduate output than the elimination of the binary divide and the creation of the 'new universities' (1993/1994). Other subjects, such as electrical and electronic engineering, had a far greater presence in the polytechnics and this is reflected in the growth of university graduates for those subjects in 1995.

[9] *Defined such that physics (including astronomy) is the only, or major, component of the degree studied (source: HESA).*

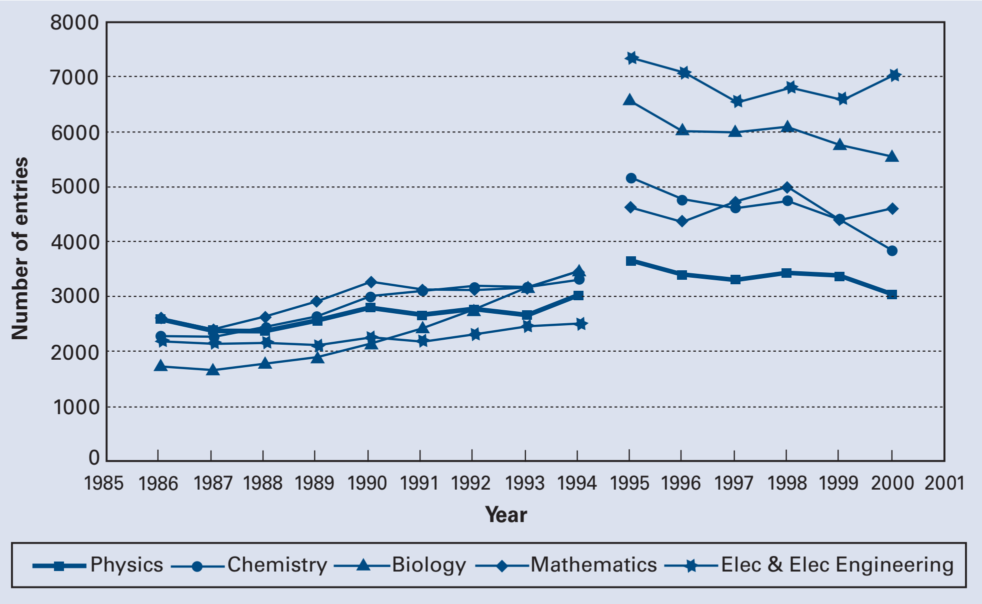
The figure of 2,300 is to be considered against a total of 265,270 first degrees awarded by UK Higher Education Institutions in 1999/2000.[10] As such, the physics graduating class represents less than 1% of the total number of graduates produced each year in the UK.

The Inquiry Panel believes that the contribution of physicists to national life is greater than measures of quantity, such as the 1% figure referred to above, would imply. The Panel suggests, in essence, that in the employment marketplace physics graduates 'punch above their weight'.

The proportion of the cohort that studies mathematics and physics at A-level and then go on to study physics at university is small; there is clearly scope for increasing the number of entrants to physics-based courses. However, given the demanding nature of the physics degree and the high level of qualifications expected on entry, the Inquiry concludes that there is little likelihood of large increases in the numbers of students studying for traditional first degrees in physics.

Figure 6

The number of first-year full-time entrants to first degrees at universities in sciences, mathematics, and electrical and electronic engineering 1985/1986–1999/2000 (source: USR 85/86-93/94 and HESA 94/95-99/00). Note: Gap relates to data from different sources.



In 1997 the National Committee of Inquiry into Higher Education (The 'Dearing Inquiry') recommended to the government that it

> *shifts the balance of funding, in a planned way, away from block grants towards a system in which funding follows the student, assessing the impact of each successive shift on institutional behaviour and the control of public expenditure, with a target of distributing at least 60 per cent of total public funding to institutions according to student choice by 2003.*[11]

Provision in higher education is currently largely determined by student choice. This cannot be in the best interests of the UK, and the Panel advocates that the government considers introducing inducements for students to study subjects deemed to be in the national interest.

Given the importance of physics discussed earlier, government and its agencies (including Local Education Authorities) and the educational and scientific communities must invest in improving the attractiveness of science, and its career options, to young people.

[10] *Source: HESA.*

[11] *National Committee of Inquiry into Higher Education (1997) Recommendation 72.*

Those involved in the development of curricula and preparation of undergraduate teaching materials should devote attention specifically to improving the attractiveness of physics, recognising the diversity of learners' interests and experience.

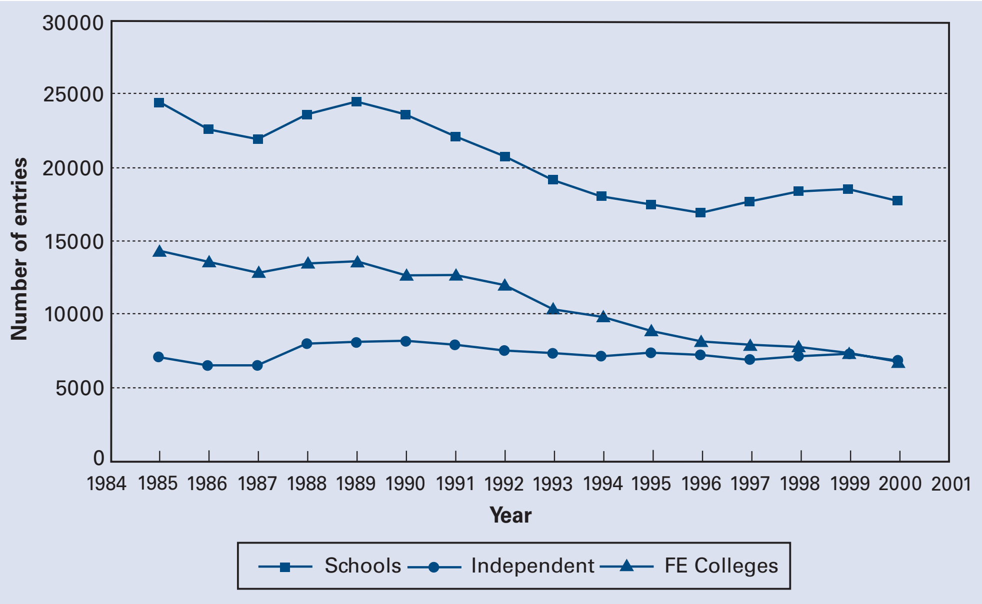
Among the sciences, physics faces a special difficulty arising largely from the subject's strength in the employment market. Young people trained in physics are able to pursue a very wide range of well-remunerated, prestigious and intellectually challenging careers. Largely as a consequence, and because of the challenges facing teachers of physics in schools and colleges (see section 2.5), not enough graduates are opting for careers in school teaching. The lack of sufficient specialist teachers of physics results in a lack of role models and informed advice for school and college students. A vicious circle has developed whereby a national shortage of physics-trained graduates has led to a reduction in the number of school and further education college teachers and in turn to a reduction in the number of physics students.

The Institute of Physics, the Standing Conference of Physics Professors, the Funding Bodies (including the Learning and Teaching Support Network Physical Sciences Subject Centre)[12] and all others involved in physics higher education must act collaboratively to improve the attractiveness of physics higher education.

The Panel supports measures aimed at broadening the diversity of physics undergraduates, but notes that in recent years there have been developments militating against such increased diversity. These developments include the fact that the teaching of physics is increasingly concentrated in 'successful' schools. Student finance reforms have increased the pressure on students to pursue more narrowly vocational higher education, especially for families with an established aversion to debt. Lastly, several smaller physics departments have closed in recent years.

Figure 7

The number of entries to A-level examinations in physics in LEA and Grant Maintained Schools, Independent Schools and Further Education, Sixth Form and Tertiary Colleges 1985–2000 (source: AQA).



Physics is becoming a subject ever more concentrated in traditional academic school environments. The Panel regards these trends as most worrying, and believes that policies should be developed in the national interest to ensure that physics remains a career opportunity for individuals from all backgrounds and in all parts of the country.

[12] *Funding Bodies refers to Department of Education, Northern Ireland; ELWa; Higher Education Funding Council for England; Scottish Higher Education Funding Council; and their agencies.*

2.5 Physics for the future – teaching

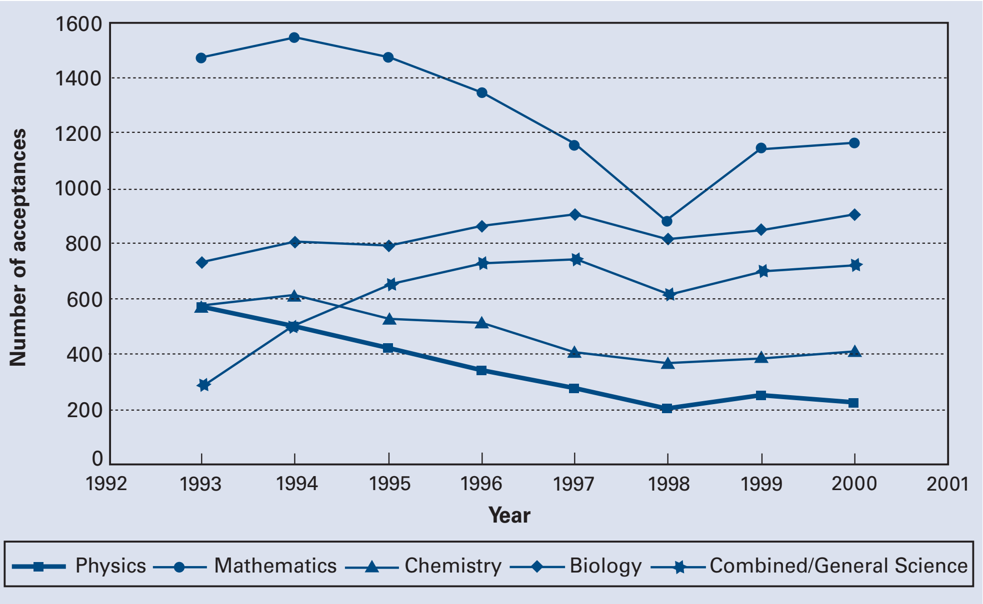
There is a crisis in the teaching of physics in our schools. A report from the Council for Science and Technology showed that, of those teaching physics at Key Stage 4 in England, 66% do not have a related degree and 29% do not even have a physics qualification at A-level.[13]

The shortage of new physics teachers and the loss of physics teachers from the profession has concerned the Panel more than any other factor facing the future of physics in the United Kingdom. Numbers of physics graduates entering teaching have fallen (figure 8).

Statistics obtained in 1998 showed that 25% of physics teachers were then over 50 years old while only 11% were under 30.[14] This compared with 17% for each age group for the teaching profession as a whole. Physics will be unable to maintain teacher numbers even if recruitment numbers can be stabilised.

Figure 8

The number of graduates accepted for PGCE courses in sciences and mathematics 1993–2000 (source: GTTR).



Efforts to improve the recruitment and retention of physics-qualified school and further education college teachers have not been successful in delivering an adequate supply to meet the direct and hidden shortages in schools, such that all pupils are exposed to good physics teaching, especially in the formative pre-16 period. Urgent and dramatic action will be needed by government, working with its agencies and independent bodies, such as the professional bodies and educational organisations.

Government and its agencies should set a target for the proportion of science classes taught to the 14–19 age range by subject specialists. They should collaborate with educational and scientific bodies in order effectively and speedily to implement policies designed to assure success in achieving the new target.

The Panel congratulates school physics teachers for the contribution that they are making today to the future health and well-being of the UK. Teachers of physics at work in our schools and colleges of further education show a dedication and a professionalism that deserves more widespread recognition and support.

[13] Science Teachers, *Council for Science and Technology, February 2000 (http://www.cst.gov.uk/).*
[14] Physics Teacher Supply, *A briefing paper for Lord Sainsbury, Science Minister, Institute of Physics Policy Paper 991 (January 1999).*

There are five general issues facing teaching:[15]

- Pay – teaching is perceived as low paid, especially to a physics graduate, and the prospects in mid-career are significantly lower than for careers in other sectors.
- Conditions – the job is perceived as stressful and schools can be unattractive places to work (albeit less so in the independent sector). Also, dealing with disruptive pupils is difficult and arguably getting worse.
- Status and standing – the status of teaching has declined compared to other professions such as law or accountancy. The teaching profession is constantly exhorted to do better and is seldom praised for its successes.
- Workload – all teachers face excessive administrative burdens.
- Laboratories, equipment and technical support – there has been inadequate investment and this has led to much equipment becoming obsolescent with fewer technicians available.

Action is needed in all these areas if the vicious circle in teaching (see section 2.4) is to be broken and more undergraduates attracted into and retained in teaching. Well paid teachers working in a pleasant environment with good resources will be able to inspire students to continue with physics and increase the numbers likely to choose to go into teaching in the future.

National interests are threatened by shortages of teachers in key subjects, such as physics. Government should accept that market forces within graduate employment dictate that teachers in shortage subjects should receive pay increases beyond the norm until the numbers of PGCE recruits rise and teacher retention is stabilised.

The Panel supports recent emphasis given to the continuing professional development of teachers, and trusts that good practice will be increased and further disseminated.[16]

It is not only pay and prospects that deter physics graduates from considering teaching as a career. The chronic shortage of physics teachers means that graduates entering the profession may find themselves in school departments where they are the only physicist and have little or no peer support. In addition, physicists considering entering teaching are sometimes put off by the widespread expectation that they should be able to teach biology and chemistry. The Panel has heard that many potential school physics teachers would feel more comfortable being asked to teach mathematics, IT or craft design technology, rather than biology or chemistry.

The Panel is concerned that increased administrative burdens placed upon teachers and increased pressures from league-tables have led to a decrease in the number of out-of-hours activities in schools. These include after school clubs which have traditionally enriched students' learning experiences in areas as diverse as music, drama and science. The Panel regrets the decreasing presence of science and astronomy clubs as this impoverishes pupils' educational experiences and makes the profession less attractive to many potential recruits.

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[15] *The Inquiry sought opinion from undergraduate students, recent graduates and teachers concerning the main factors deterring young people from entering the teaching profession. The reasons specified give rise to the bullet points presented above.*
[16] Science Teachers, *Council for Science and Technology, February 2000 (http://www.cst.gov.uk/) and Science in Schools, House of Lords Select Committee on Science and Technology, 1st Report session 2000-01 (HL Paper 49).*

School science facilities tend to be expensive to maintain, leading to equipment being old and not representative of the type of equipment used in industry/ research. School students often have more sophisticated computers at home than are available in the school science laboratory. Laboratories should be modernised and the infrastructure of school science departments better funded. Improvements in these areas will not only improve the student learning experience but also improve the attractiveness of the teaching profession. Government should encourage (perhaps via fiscal incentives) local industry sponsorship of school physics departments, enabling 'state of the art' laboratory and IT equipment to be used by pupils.

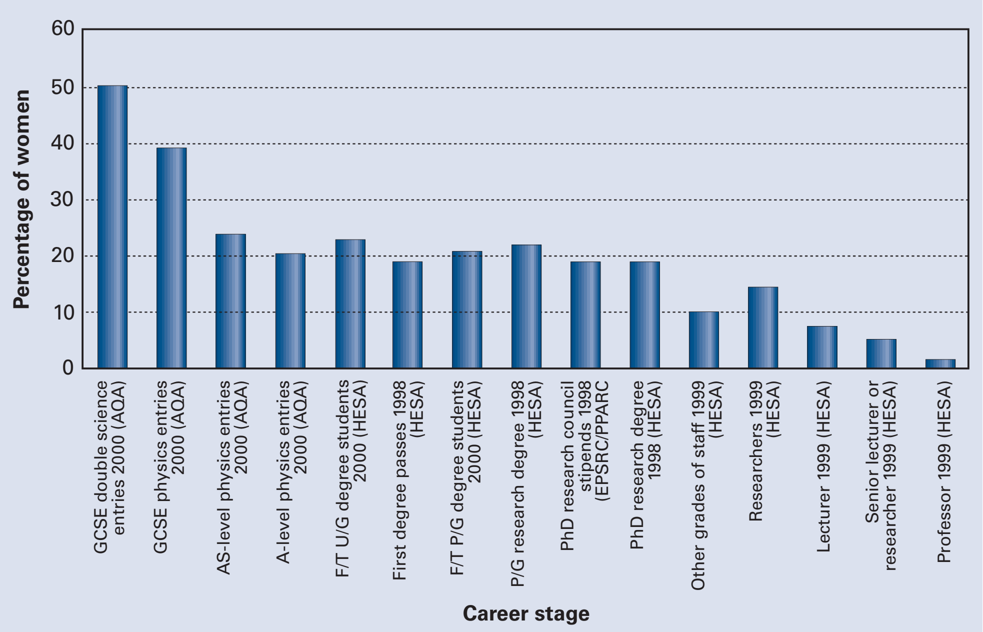
The Panel recommends that all university physics departments look to creating partnerships with their local school physics departments. The contact with the physics community, access to expertise, equipment and libraries will provide a much more supportive environment within which physics teachers can operate and motivate young people.

2.6 Women in physics

Women are under-represented in post-16 education and higher education in physics. Greater efforts need to be made to encourage more girls at all levels to study physics. Particular efforts need to be targeted on Key Stage 3 (11–14 years) in particular, where there is a noticeable decline in girls' interest in physics. The Institute of Physics and government should do more to promote to women the advantages of physics-based careers.

Figure 9

The percentage of women in physics at different stages in education and research (source: AQA/HESA/ EPSRC/PPARC).



The low representation of women is an even more severe problem in engineering. There could, therefore, be value in cognate professions working together to tackle what appears to be a common issue.

Concern is expressed that in the past curricula at all levels have unwittingly made physics more attractive to boys than to girls. The Panel is pleased that examples that preferentially appeal to the interests of boys, such as those based upon snooker or motorcycles, are now a rarity in compulsory education. There have, in the past, been problems at A-level, but the new Advancing Physics course developed by the Institute opens with discussion of the information that can be obtained from an ultrasound image of a 20-week-old foetus.[17] The Panel

[17] Advancing Physics AS, *Institute of Physics Publishing, Bristol 2000.*

is of the view that future curriculum development should intensify efforts to strengthen female friendly delivery of physics. The Panel would support the setting up of a research project to investigate further – in a physics context – the learning processes of men and women.

Women enrolled on physics courses do at least as well, in their degrees, as their male counterparts. Within physics there is anecdotal evidence and some statistical evidence[18] that women are particularly attracted to the following sub-fields:

- theoretical physics
- astronomy
- medical physics
- polymer physics
- particle physics.

whereas relatively few appear to be attracted to the following sub-fields:

- low-temperature physics
- semiconductor physics
- nuclear physics
- electronics.

The Panel was told that joint and combined honours courses appeal well to female students. It is hoped that efforts to increase diversity and breadth of provision will be able to assist in the process of attracting more girls into physics and related disciplines.

The Athena Project, aimed at improving the careers of women in scientific higher education, has, despite modest resources, been able to do much valuable work.[19] Initiatives such as these are supporting women who will constitute the role models for girls interested in pursuing a career in science and technology.

There have been a number of useful projects concerned with increasing the popularity of science generally among girls and young women. These have been brought together under the auspices of the Office of Science and Technology.[20] The UK is also well represented in European networks designed to improve the situation for women in science, engineering and technology.[21]

[18] *Survey-World.com survey, see Appendix IV,* Community Consultation Summary Findings.
[19] *See www.athena.ic.ac.uk.*
[20] *See www.set4women.gov.uk/set4women/schools/index.htm.*
[21] *See www.shu.ac.uk/witec/.*

3 Delivery and Content

In 2000 the UK graduated 2,400 students with a first degree in physics, where physics was the only subject of study referred to in the qualification title or was the majority subject of study. UCAS lists 574 distinct degree courses where physics was a majority component.[22] Physics, of course, is not unique in responding to market pressures by offering a wide range of degrees. There is evidence, however, that in some cases it would be appropriate for integration between physics and the other components of joint/combined degrees to be improved. This is particularly important for degrees combining elements from cognate disciplines. In these cases there appears to be the greatest opportunity for degrees to represent more than simply the sum of their modular parts.

Consistent with themes of variety and coherence, the Panel recommends that there should be greater scale and diversity of physics provision in higher education, so as to address evolving national and regional needs. Universities are rightly autonomous; thus physics departments and science faculties should be free to make local decisions appropriate to the needs of all concerned parties – students, employers, government, etc. Nonetheless the Panel believes that physics has a contribution to make to all universities, although the nature and extent of the provision will vary greatly from one institution to another.[23]

The MPhys and the BSc degrees in physics are structurally linked within each university physics department. Between them they characterise the primary undergraduate outputs of every university physics department. Nationally they constitute a wide range of course types, satisfying a range of student and employer demands.

The demand pressures discussed in Chapter 2 imply that there are opportunities for universities to offer more general physical science-based courses to attract those students for whom traditional physics degrees are not attractive. The Panel concludes, in addition, that the only way to increase significantly the numbers of people benefiting from physics training at university is to offer a greater breadth and variety of physics-based degrees.

Figure 10 shows the undergraduate subjects chosen by students who secured A-level passes in both physics and mathematics in each of the years 1996–2000: these are students possessing the traditional pre-requisite A-level qualifications for admission to a physics degree. It is apparent that physics is one of four similarly popular undergraduate choices for this community.

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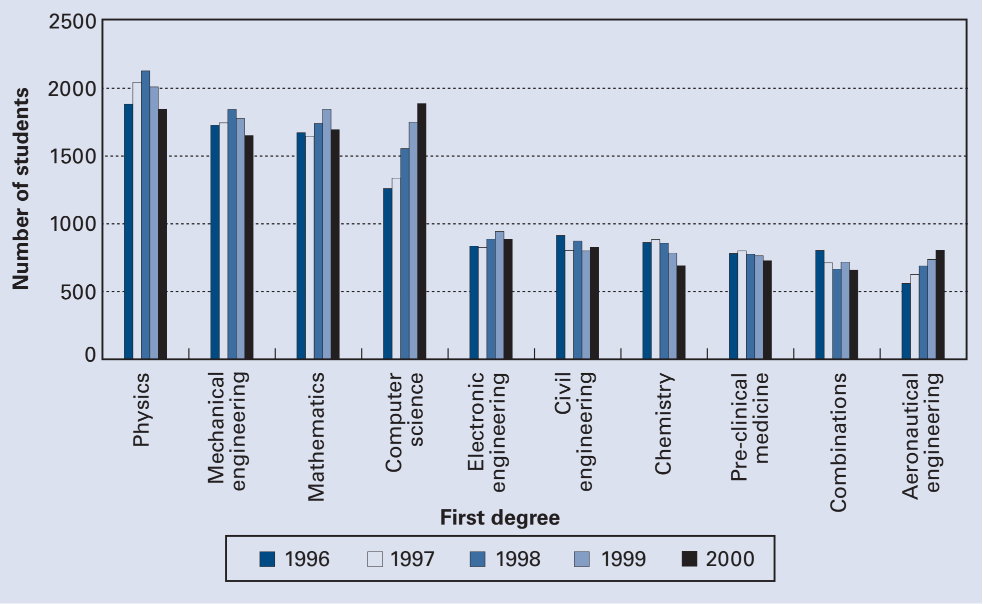
[22] *Source: UCAS – 574 distinct 'F3' coded courses were available in 2000.*

[23] *See Appendix III,* Physics Higher Education Models.

Figure 10

First degree destinations of students who took physics and mathematics A-level 1996–2000 (source: UCAS).

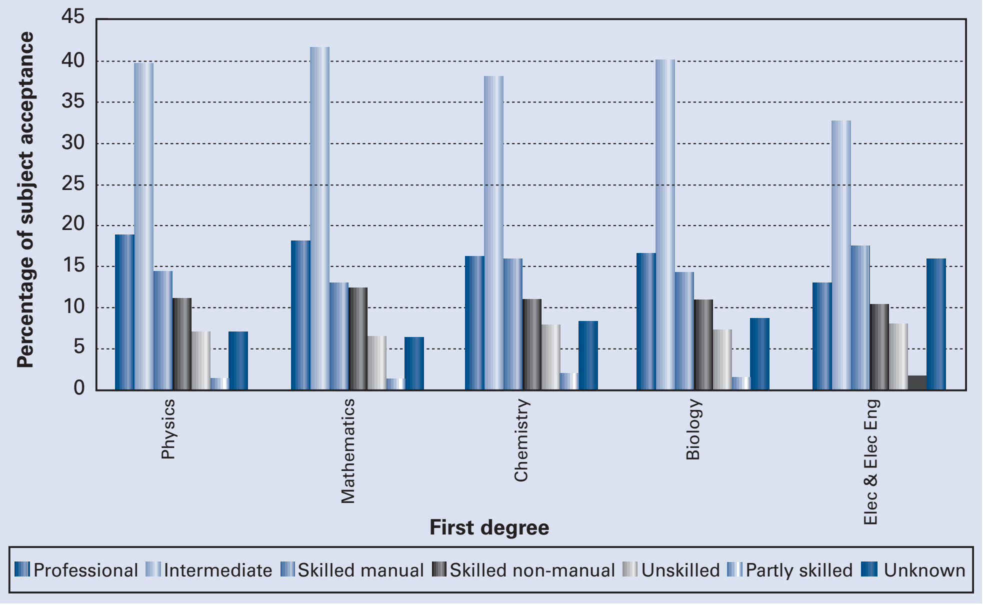


The Inquiry is concerned that recent shifts in undergraduate student support (away from grants and towards loans and tuition fees) might be generating a shift in student choice away from traditional academic subjects towards those with a more vocational flavour. The Inquiry Panel recognises that higher education resources should reflect student choice, but believes that cognizance should be taken of national needs in shortage areas (see section 2.4).

The Inquiry's survey of graduates reveals that approximately one third of respondents graduated with no debt.[24] This fraction was surprisingly large. Further consultation with the physics community,[25] however, indicated that it is expected to fall in future as general indebtedness increases among undergraduates. At present there is no indication (see figure 11) that physics suffers from unusually affluent demographics for its undergraduate population, but the full effect of the introduction of student fees and the abolition of student grants has yet to be felt.

Figure 11

Social class background of acceptances to UK first degrees as a percentage of the total acceptance 1996–2000 (source: UCAS).



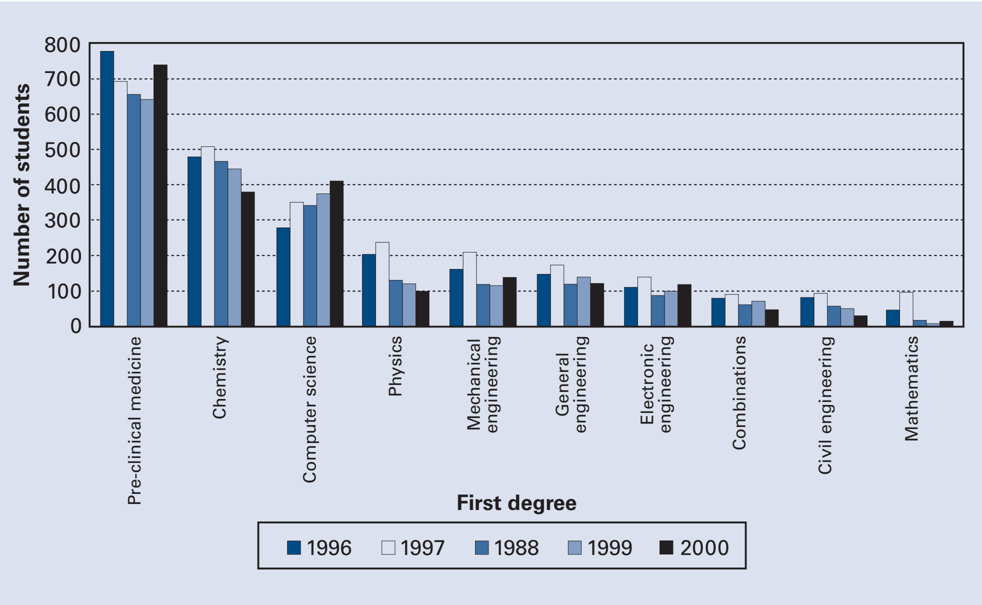
[24] *See Appendix IV,* Community Consultation Summary Findings.
[25] *Including via an article in* Physics World *(May 2001) p52.*

It is government policy to increase participation in higher education: there will, therefore, be an increasing supply of graduates. Accordingly, there is now an opportunity for university physics departments to provide courses in the physical sciences for those without advanced qualifications in mathematics. Section 3.3 will consider this point further and suggest that there is an opportunity for a new physics-based undergraduate programme of study that might, depending on local institutional choice, replace or sit alongside the existing BSc and MPhys degrees in physics. In this report, the proposal for a new physics-based course will use the phrase 'New Degree' as a working title.

In addition to the demands of employers, any broadening and extension of undergraduate provision towards a New Degree must meet the demands of students (e.g. those studying physics A-level but not mathematics). As reforms to 16–19 education progress, it is expected that an increasing number of students will choose to study AS- and A-level physics without simultaneously studying mathematics. Figure 12 illustrates the courses currently studied at university by physics students who have not studied A-level mathematics. It is noteworthy that the small number of such students going on to study a physics degree without A-level mathematics has been decreasing in recent years. It would appear that students of this type might be attracted to an expanded and more appropriate range of undergraduate options, including the New Degree discussed in section 3.3.

Figure 12

First degree destinations of students who took physics A-level, but not mathematics 1996–2000 (source: UCAS).



Physics undergraduate teaching in British universities is of a very high standard. In the recent (1998–2000) Quality Assurance Agency Subject Reviews of physics for universities in England, Wales and Northern Ireland (EWNI), departments averaged 22.6 points out of a maximum of 24.[26] The high quality of physics undergraduate teaching is reaffirmed by the results of the Inquiry's Web-based survey of undergraduates and recent graduates, which found 82% of current undergraduates agreeing (or strongly agreeing) that their teaching is 'good'.[27]

These results notwithstanding, opportunity always exists to develop new teaching skills and introduce new techniques. The Panel supports, therefore, the development and maintenance of teaching skills in universities. Furthermore, the Panel recommends that teaching be given due regard in respect of individual academics' career progression and university funding policies. Bodies such as the Institute for Learning and Teaching in Higher

[26] *Source: Quality Assurance Agency.*

[27] *See Appendix IV,* Community Consultation Summary Findings.

Education (ILT) have the potential to contribute to this process, but it is possibly too early to see the results. The Learning and Teaching Support Network Physical Sciences Subject Centre has got off to a good start in its attempts to disseminate best practice and to develop beneficial innovation in scientific higher education. Time will show whether these bodies represent the best route to an improvement in this area.

3.1 MPhys/MSci

The Inquiry concludes without reservation that the four-year undergraduate integrated masters programmes launched in the years after the *Future Pattern* Report represent educationally rich, highly relevant first degrees. These degrees have succeeded admirably as assessed against the *demand, delivery and content,* and *resources and access* criteria adopted by this Inquiry.

The MPhys extended first degrees in physics have secured a place at the heart of the subject. These degrees are essential for training the highly skilled workers needed by industry, academe and commerce. All higher education policies in physics should act so as to enhance and strengthen this qualification.

With regard to employer demands, MPhys graduates are of great value, as they are intellectually excited by new ideas, have a clear quantitative understanding of the major principles of physics and possess the ability to manipulate mathematical models. Importantly, MPhys degrees are comprehensive first degrees in physics and, as such, particular specialisms are introduced and appropriate research topics incorporated. This approach to the subject is welcomed by industrial and business employers. Employers are looking for the ability to grasp quickly (and in a quantitative way) the principles underlying novel commercial situations.

The skills acquired during an MPhys extend beyond application in manufacturing and production. MPhys graduates are particularly suitable for a wide variety of positions in commerce, finance, and public service. The specific attributes acquired by all MPhys graduates are a deeper knowledge of the subject of physics and acquisition of research skills. In addition, employers value the graduates'

- proficiency with mathematics;
- familiarity with computers;
- programming skills;
- presentation of complex topics;
- data handling and modelling.

Evidence from regional consultation fora, the Web-based survey of undergraduates, and consultation with employers shows that MPhys degrees preferentially attract students with intellectual curiosity and with interests in facing a challenging learning experience.[28]

Clearly, the MPhys degree is not merely for those students intending to pursue a career in academic physics (e.g. by studying for a PhD in physics), but also for those intending to pursue careers in industry and commerce where 'masters level' physics skills are beneficial. This balance of demands upon the MPhys should be reflected in the programme of study. University physics departments are urged to ensure proper emphasis of transferable skills in MPhys programmes.

[28] *The Inquiry's Web-based survey of undergraduates found that 59% of MPhys students were primarily motivated to study physics by a fascination for space or the physical properties of matter. The equivalent proportion for those studying other first degrees in physics was 48%.*

The Inquiry has heard from employers that there are no concerns concerning the scientific expertise of MPhys graduates.[29]

Physics is a quantitative subject and the MPhys (as indeed the BSc) degree must continue to reflect this. Qualifications obtained during a student's final years at school are changing. Following 2001, most students in EWNI will be studying for AS-levels at the age of 17 followed by A-levels a year later. This poses something of a dilemma for university entrance tutors, but the Panel is of the view that MPhys entrants should have the highest school- leaving attainment in both physics and mathematics. However, the AS/A2 system will enable tutors to take a more flexible view, with the opportunity of attracting students into physics who have not followed traditional paths. In Scotland, where admissions are already more flexible than in the rest of the UK, school-leaving qualifications in both mathematics and physics are expected to continue to form the basis for admission to MPhys and BSc physics degrees.

University physics departments must continue to maintain and enhance the quality of their MPhys degrees, in particular to ensure that they satisfy the requirements for level 4 of the Quality Assurance Agency qualifications framework or, in Scotland, 'SHE M'. It is also important for European mobility of highly qualified workers that the MPhys degree should equate with that of continental European Masters degrees. The Institute of Physics should use its influence with the UK government and pan-European educational bodies to ensure that the MPhys degree is recognised as a 'second cycle' qualification within the Bologna structure.[30]

In Europe, the momentum towards a 'convergence' in the 'architectures' of European higher education presents difficulties for physics. The evolution of this policy from the Sorbonne to Prague meetings has – in emphasising architecture over content – failed to recognise or accommodate the developments in UK physics education which have led to one of Europe's most educationally enriching degree programmes – the MPhys.

3.2 BSc Honours Physics

There is consensus amongst employers and academics that the BSc Honours degree in physics should remain as a major element of British higher education in physics. BSc degrees in physics have long-standing employer recognition and a well-deserved reputation for quantitative rigour.

In 2000, 63% of the physics final year undergraduate cohort graduated with BSc degrees, the rest with MPhys degrees.[31]

Substantial national and regional provision of BSc Honours degrees in physics must be maintained in order to satisfy clear demands from students and employers for degrees of this type. It is not possible to predict how demands for the BSc and MPhys degrees will alter in future. It can be argued that demands for the BSc degree will grow in the coming years. largely as a consequence of changes to student finance. On the other hand there will be an increasing tendency for students to seek higher qualifications beyond the bachelors level. The Panel suggests that the Institute maintains a watching brief on the balance of student choice between the BSc and the MPhys. If there are indications that for reasons of individual student finance the national interest is not being served, then representation should be made by the Institute and the Standing Conference of Physics Professors to government and its agencies. Whilst all physics departments will be conscious of the importance of MPhys

[29] *See section 2.3.*

[30] *See Appendix II*, Physics Higher Education – the European Context.

[31] *Pass lists for the year 2000.*

graduates for advanced study and research, university physics departments as a whole must continue to recognise the importance to UK industry and commerce of the BSc Honours degree in physics.

The Panel notes that the bachelors degree in physics in many universities contains almost as much physics-based core material as the associated MPhys degree. It was intended in the early 1990s that the content of the revised BSc should be reduced by one third. This was in order to teach better the fundamentals of the subject. The Panel notes that this rebalancing of physics content has not, in some cases, gone as far as it should, and departments are recommended to consider these issues afresh.

3.3 Increasing variety of provision – a New Degree?

Central to the Panel's deliberations was an examination of whether physics is playing its fullest role in British higher education. In essence the Panel questioned whether physics departments had appropriately confronted the Dearing Inquiry's emphasis on the need to strike a balance between depth and breadth in undergraduate provision.

The 1997 Dearing Report stated:[32]

We recommend that all institutions of higher education should, over the medium term, review the programmes they offer:

- *with a view to securing a better balance between breadth and depth across programmes than currently exists;*
- *so that all undergraduate programmes include sufficient breadth to enable specialists to understand their specialism within its context.*

As the Undergraduate Physics Inquiry developed, the Panel considered how the sum total of activities within all physics departments could best contribute to Dearing's ideas for balance between depth and breadth across programmes. These considerations were discussed in the context of a continued expansion for higher education as a whole. Having considered the issues of broadened physics education from several perspectives, one proposal, more than any other appeared to have merit – a New Degree drawing heavily upon physics but being more interdisciplinary in focus.

Key attributes of the proposed New Degree would include:

- more flexible pre-requisites for entry;
- an intention to build mathematical knowledge and competence during the course of study;
- training of students for a broad base of technical or scientifically related employment areas;
- encouragement of a breadth of thinking and support for a multi-disciplinary approach to problems.

The Panel believes that the proposed New Degree has the potential to satisfy several national needs that are at present being inadequately served by the MPhys, the physics BSc and honours degrees in other subjects. These include:

- **the needs of students**

The Panel notes that only one in 20 students studying physics at A-level or Scottish Highers goes on to study for a degree in physics. Those that do tend to

[32] *National Committee of Inquiry into Higher Education (1997), recommendation 16.*

have very high grades in both mathematics and physics.[33] The broadening of post-16 studies will increasingly result in those young people expressing an interest in the physical sciences and engineering but finding themselves unable to fit into the conventional physics degree. Admissions tutors should recognise diverse routes of access and support measures that permit learners from all backgrounds, and with all types of personal circumstances, to find appropriate routes into higher education. For students, and physics departments, it appears likely that the proposed New Degree could do much to improve access to physics departments.

- **the needs of employers**

We live in an increasingly technological economy where the demand for manual skills is decreasing – there will increasingly be a need for employees with graduate skills, even in sectors that have not previously demanded graduates. The Panel suggests that the proposed New Degree will be able to satisfy employer demands in a broad range of areas, many of which are becoming increasingly technological. These include environmental monitoring, medical physics, high-technology entrepreneurship, intellectual property law, management consultancy, laboratory support and teaching.

- **the need for science teachers**

As discussed in section 2.5 there is a crisis facing the teaching of physics in schools and colleges. Large numbers of teachers qualified in physics are needed to fill existing vacancies, and greater numbers will be needed in the future. Despite the increasing demand, there is no rise in the number of physics graduates choosing to pursue a career teaching in schools.[34] The Panel concludes that, as physicists will continue to be in high demand in the employment market, a new source of graduates well equipped to teach physics classes in schools is needed. The Panel believes that the proposed New Degree is well placed to prepare students for a career in school physics teaching. A-level physics is a quantitative course requiring teachers comfortable with quantitative techniques. In this context, it is important to emphasise that the proposed New Degree is not a non-mathematical degree. The lack of emphasis on mathematics refers to the pre-requisite qualifications for entry to the course, not to the style of the undergraduate teaching nor to the mathematical skills on graduation.

Despite having given consideration to the possible benefits of the proposed New Degree, the Panel recognises that several issues remain unresolved. The Panel recommends that a Working Group representing interested parties be tasked with further developing the proposal.

The Panel recommends that the New Degree Working Group should:

- explore demand from potential students and employers;
- determine the best level for the degree (bachelors, bachelors and associated integrated masters, foundation degree and linked bachelors, etc);
- address the funding of the degree;
- consider the types of institutional providers;
- establish the range of material to be covered;
- develop a launch strategy for the degree;
- prepare a report to be published in 2002.

[33] *See figure 4.*
[34] *See figure 8.*

3.4 Sub-degree provision

The Panel notes that the new qualifications frameworks emphasise the importance of sub-degree provision, but at present there is little delivery in physics at these levels.[35]

A noteworthy exception, however, is the provision by several university physics departments of one-year conversion courses for students. These courses are often termed 'foundation years' and are especially valuable for those students entering a physics department without demonstrated skills in normally pre-requisite areas, such as mathematics. The Panel heard, during regional consultations, that these 'foundation years' are extremely beneficial to the students involved, and the Panel strongly supports such provision. The Panel suggests that there is much to be gained by departments sharing good practice in access policies.

The Panel considered whether Foundation Degrees in physics might represent an opportunity to help alleviate the damaging shortage of physics teachers. On balance, however, it was decided that the New Degree discussed earlier (section 3.3) would probably have more to offer in this respect.

Before launching Foundation Degrees in physics, the Panel heard that departments would be well advised to explore fully the reasons behind the decline in Higher National Diplomas in science subjects.

3.5 Mathematics in physics degrees

Physics is a quantitative science, and mathematics and physics are indivisible. It is essential, therefore, that the BSc Honours degree in physics and the MPhys degree remain as strongly mathematical courses. This is especially important, as mathematical proficiency is one of the most important skills in making physicists attractive to employers.

The Panel heard repeatedly from students and departments that many undergraduate students do not have a confident grasp of all the mathematical techniques required by undergraduate degrees in physics. The problems faced by some students have been described as arising from 'translation difficulties'; some students have great difficulty in understanding how a mathematical formula relates to a physical reality, while others have the inverse problem, in finding difficulty modelling a physical problem mathematically.

The Panel concludes that the problem rests neither with the students nor with the teachers of physics or mathematics in schools; rather it is an outcome of changes in post-16 education. Departments are urged to recognise the difficulties faced by students and to accept that these difficulties will not disappear without action on the part of physics departments. It is clear, however, that some university physics departments have already moved successfully in this direction and are successfully adapting teaching and learning to accommodate the evolving issue of mathematics preparedness.

Effective addressing of the mathematical needs of undergraduates requires greater emphasis on mathematical topics in the early years of the BSc and MPhys programmes. How this can best be achieved is the responsibility of the university concerned. With care, physics has the potential to become a more attractive programme of study for those less well-prepared in mathematics. The true nature of any changes to mathematical expectations should be made clear by physics department admissions tutors to potential degree applicants and their advisers.

[35] *See National Qualifications Frameworks (Quality Assurance Agency).*

The Panel recognises that different universities deliver effective mathematical education to physicists in diverse ways. The Panel does not wish to be prescriptive as to how mathematics is best taught to physicists. One thing, however, is clear. Physics departments must be actively involved in specifying how the mathematics components of their degrees are to be provided. The Inquiry heard of instances where universities' senior management favoured, or required, structures that (physicists reported) were poorly serving the mathematical needs of physics students. Examples included instances where mathematics faculty provided service teaching to a wide range of university departments, including physics, but where the diverse needs of students from these various departments were poorly served. Service teaching models can work well, but they require the active collaboration and engagement of all participating departments.

The Panel recognises that whilst there are benefits to be derived from integrating the development of some mathematical skills within the core physics curriculum, there are examples of successful alternative models. The Inquiry concurs with many of the findings of the recent London Mathematical Society, Institute of Mathematics and its Applications and Royal Statistical Society joint report entitled *Tackling the Mathematics Problem*.[36]

The Institute of Physics should examine the possibility of producing a series of mathematics modules specifically designed to address the mathematical needs of those studying degree programmes in physics. These would build on the experience of the FLAP (Flexible Learning Approach to Physics) project. It is essential that any new materials developed in this way are developed in consultation with departments and are widely publicised.

In seeking to improve physics higher education in a cost-effective fashion, the Panel's attention focused on the IT skills of physics students on entry to university and on graduation with a physics degree. The Panel has heard that increasingly students arrive at university with much experience in how to install novel software or hardware configurations on computers. Students are generally familiar with e-mail and the World Wide Web and many have well-developed skills with computer games. The skills they lack, however, include many that could be provided by a physics degree, such as programming in commercially relevant computer languages (C++, Visual Basic, Java, etc); advanced word processing; and experience with spread sheets and computer databases. Students benefit from their physics studies in being able to use computers for data logging and data modelling. The Panel urges that university departments aim to build upon students' existing IT skills, and explore ways to improve physics education through greater use of IT.

The Panel cautions, however, that whilst IT can be used to cut costs or to improve upon existing provision, it is especially difficult to improve the learning experience of the student while simultaneously aiming to reduce costs to the department. Developments in IT provision demand additional resources and would benefit from inter-departmental sharing of best practice so as to maximise all-round benefit.

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[36] *The report may be downloaded from the following Web site: www.lms.ac.uk/policy/tackling/report.html.*

4 Resources and Access

The recent Subject Reviews conducted by the Quality Assurance Agency (QAA) have demonstrated the high quality of undergraduate physics teaching in UK universities.[37] The Inquiry's surveys and nationwide meetings reinforced the QAA's conclusions.

Physics is by its nature a resource-intensive subject to teach in both teaching staff and laboratory provision. In the past ten years the university physics student : staff ratio has increased, although less dramatically than has been seen in other subjects as there were relatively few physics departments in the former polytechnics.[38] As industry's demands for graduates with a high degree of technical knowledge and expertise increases, it is incumbent upon universities to have modern instruments and equipment. Allowing for increasingly rapid depreciation, the cost of providing modern equipment has risen at a faster rate than inflation. Both the 2000 international review of physics and astronomy research and evidence presented to this Inquiry demonstrates that universities are under pressure for resources for undergraduate teaching.

In order to maintain the existing high standards in undergraduate physics, the Funding Bodies should monitor and review the Price Groups allocated to laboratory sciences.

The Inquiry supports improvements in access to MPhys and BSc degrees in physics. In addition, the Panel believes that the proposed New Degree (see section 3.3) has much to offer by way of increased access to, and participation in, scientific higher education. As a new course, there will be opportunities to construct provision to meet demands for part-time learning, to provide a wide base of regional provision and to offer a greater flexibility of entry qualifications (especially in mathematics).

This New Degree will be subject to statutory and professional body accreditation schemes and quality assurance processes – all these bodies should ensure that they encourage and support diversity and innovation in scientific higher education provision.

The course content common to the MPhys and BSc degrees enables a flexible approach, with decisions being made as to which to pursue being taken at the end of the second year (EWNI). However, many local authorities and other organisations which provide contributions to student fees currently insist on such choices being made earlier. This inflexibility is neither in the students' nor the national interest, and the Panel recommends such structural barriers be removed.

The Panel welcomes developments whereby physics departments at different institutions have collaborated in the development of course modules and programme offerings, particularly for the advanced courses which make up the final year of the MPhys. The Panel concludes that this good practice should be more widely adopted by departments.

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[37] *For Quality Assurance Agency subject review reports, see: http://www.qaa.ac.uk/revreps/subjrev/intro.htm.*
[38] *Statistics facilitating various measures of student : staff ratio are available from HESA.*

Figure 13

Ethnic origin of home acceptances to first degrees in sciences, mathematics, and electrical and electronic engineering as a percentage of the total acceptance, aggregated for 1996–2000 (source: UCAS).

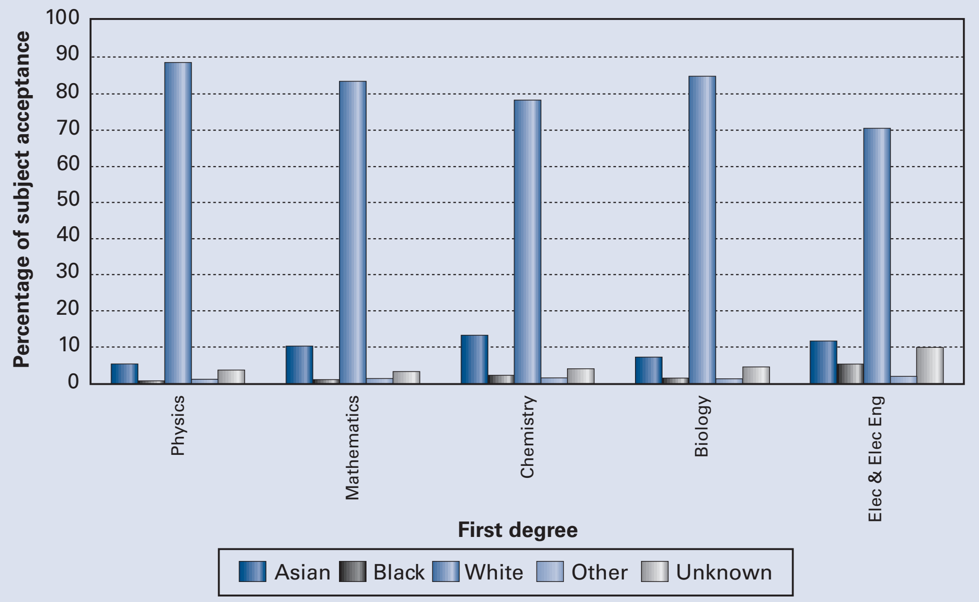

Figure 13 shows that physics currently attracts fewer students from ethnic minorities than other subjects. The Panel recommends that university physics departments examine further what might be done to attract more minority students into the subject. The Panel suggests that by consciously drawing more widely on the pool of potential students, departments may better address the national demand for physicists.

4.1 Regional provision

Since 1994 the number of universities offering degrees in physics has declined from 79 to 53.[39] One consequence of such a decline is the emergence of 'deserts' in undergraduate physics teaching – regions of the UK not served by a locally focused university physics department. The clear gaps in such provision are of concern to the Panel.

Why do such gaps in regional provision matter?

- There is a need to educate and train undergraduate and postgraduate students in physics in circumstances where student mobility is increasingly less practicable, particularly with the introduction of loans leading students to reside at home and the increased presence of mature students, many of whom have young families. Improved regional provision has much to contribute to higher education access in physics. Departments may wish to re-evaluate their provision in a regional context and incorporate improvements for part-time learners and students with physical disabilities.
- The needs of industry, particularly small locally based companies, for university support in research and development must be satisfied. This includes the supply of trained personnel and the access to research expertise provided by universities.
- Physics teachers need to be supported via increased contacts with local university physics departments. Such linkages might include formal postgraduate training, informal update courses or structured continuing professional development. By spending time in university physics departments, physics teachers could maintain familiarity with modern laboratory equipment and benefit from individual mentoring from university faculty.

[39] Physics on Course *annual publication of the Institute of Physics.*

The Inquiry notes that, in some regions of the UK, closure of an existing physics department would be extremely harmful, as assessed by the three criteria set out above. These regions include south-west England, Northern Ireland, and parts of Scotland and Wales.

In summary, the Inquiry recommends to the Funding Bodies that (as far as possible) there should be university level activity in teaching and research in all regions of the UK where there are concentrations of population and industry.

It has been argued that adequate regional provision might be provided by the Open University and by Web-based courses provided, in particular, by prestigious North American universities.

Physics is an experimental subject and there is a need for provision of high quality laboratory teaching based upon modern equipment and techniques. Web-based education tends to be remote and lacks many of the most important aspects of the university experience, such as mentors, peers and role models. The Open University has much experience in combining distance education with direct personal contact and support.

If a large university places its physics course materials on the Internet for public access, that can be beneficial (for instance to universities in developing countries), but by and of itself it does very little to ensure the regional presence of physics higher education in the UK. Increasingly large international universities may be interested in providing higher education to British students. The Panel believes that, in physics, such moves will not compensate for the shortfalls in UK regional provision discussed earlier, except perhaps if international players enter into partnership with existing local higher education institutions.

The Inquiry notes that the Open University regards itself as being the 'local' university for everyone in the UK, and that its mode of teaching and learning complements rather than competes with other universities. The Open University is a local university, a national university but also a global university, with more students studying overseas than is the case for any other university. It therefore does make a valuable contribution to the teaching of physics at university level in the UK regions. However, the Open University recognises that it is not a substitute for traditional university education.

While physics undergraduates continue to move far from home to attend university,[40] physics departments will not benefit directly from the increasing activities of their academics to convey to the local schools and public the excitement and relevance of physics. The beneficiaries of such activities are typically universities 200km away from the university providing the outreach. In lecturing to the public, academics are therefore acting altruistically. Such activities are extremely important nationally and should be regarded by all concerned with higher education policy as an essential element of any good university's portfolio of activities. The universities and the Funding Bodies should take such activities into consideration when decisions are made concerning the future of physics departments.

As members of the Inquiry Panel toured the UK, one particular theme emerged. The interests of physics, physicists and the country as a whole will be best served if the physics community in its fullest sense acts collaboratively. The Panel was particularly impressed that representatives from 11 of the 13 Scottish universities (including those without a physics department) participated in the Inquiry's regional fora. This process of dialogue between very diverse institutions showed that the roles and interests of these various institutions were more complementary than competitive.

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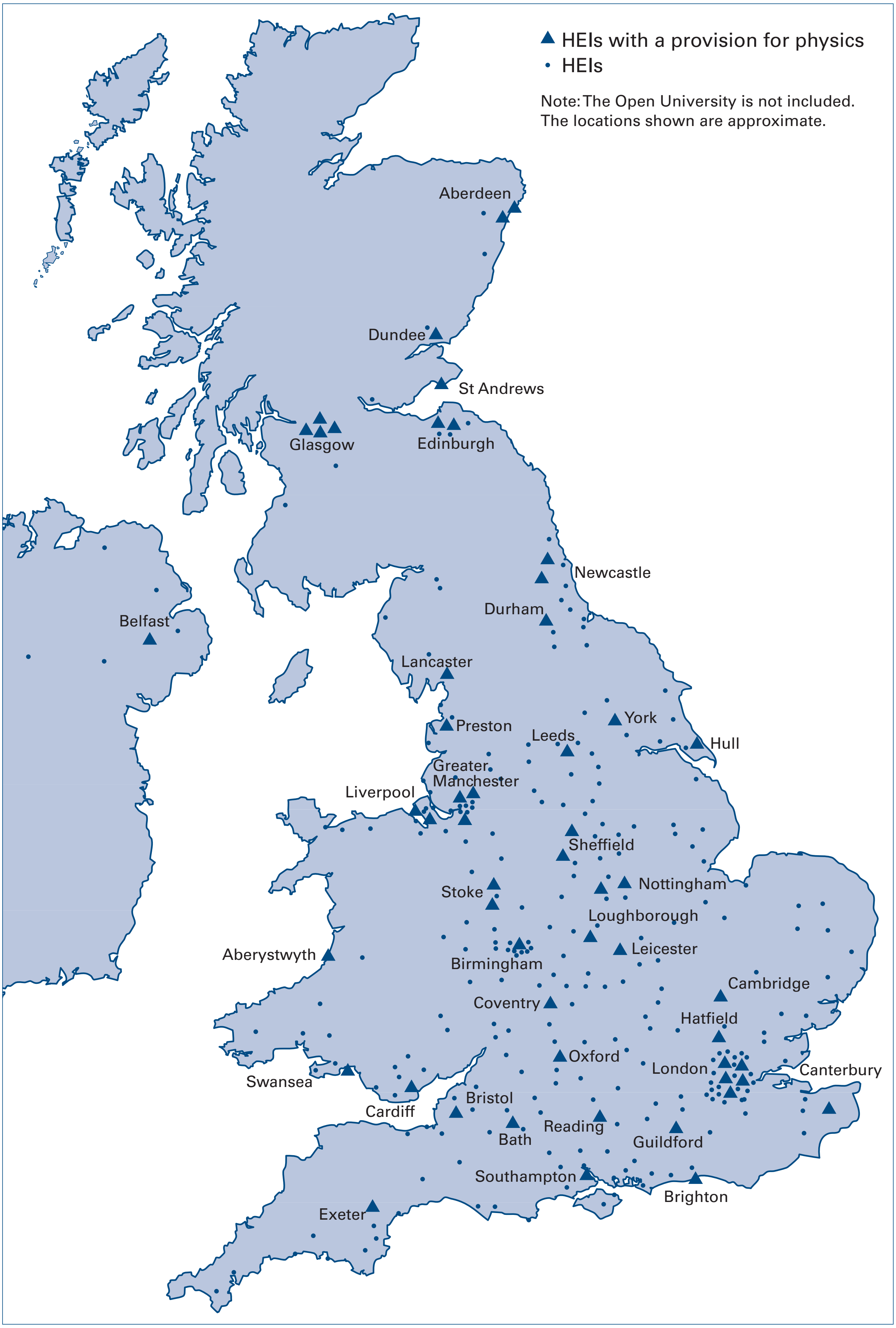
[40] *See Appendix IV,* Community Consultation Summary Findings.

Figure 14

Regional provision of physics in the UK as listed in Physics on Course 2001.



Pressures for students and pressure for funds tend to lead to competition, but the Inquiry notes that there are already several important examples of regional collaboration in physics provision. The Panel supports these developments as routes to enrich the educational experience of undergraduates and to foster physics in institutions with diverse profiles. Together, departments can establish an imaginative and progressive vision for the future of the subject, and thereby better assure the continued health of physics in the UK.

I Inquiry Membership, Terms of Reference and Methodology

The first task facing the Inquiry Panel in the autumn of 2000 was to consider and propose modification to its draft terms of reference. The Panel's principal suggestion to the Council of the Institute of Physics was that greater weight be given in the Terms of Reference to the problems associated with the teaching of physics in schools. The modified terms of reference were approved by the Council at its meeting on 19 October 2000.

The initial Panel membership also recommended that gaps within its knowledge base be filled. Accordingly, several extra members were co-opted during the late autumn of 2000, bringing the membership to 11, excluding secretariat.

Panel Membership

Sir Peter Williams, Chair
President, Institute of Physics, and Master, St Catherine's College, Oxford

Professor Mick Brown
Professor of Physics, Cavendish Laboratory, Cambridge University

Professor Gillian Gehring
Professor of Physics, Sheffield University

Dr Jessica James
London Head, Strategic Risk Management Advisory, Bank One

Dr Alun Jones
Chief Executive, Institute of Physics

Professor Jon Ogborn
Institute of Education, Sussex University, and Professor Emeritus, Institute of Education, London University; Project Director, Advancing Physics

Professor Stuart Palmer
Head, Department of Physics, University of Warwick

Ms Helen Reynolds
Head of Physics, Gosford Hill School, Kidlington, Oxfordshire.

Dr Eddie Slade
Chair, Institute of Physics Degree Accreditation Committee

Dr Bruce Smith
Chairman, Economic and Social Research Council

Professor David Wallace
Vice-Chancellor, Loughborough University

From the first days of the Inquiry an informative Web page had been developed, and once the terms of reference and the Panel membership had been finalised this information was immediately published on the Inquiry's Web page.

Terms of Reference

To review the nature, content and delivery of university physics courses, with due regard to:

Demand

- the intellectual vitality of physics and its ongoing contribution to society;
- the demand for physics courses, including four-year honours degrees;
- bachelors degrees, sub-degree qualifications, combined honours programmes and service teaching, at universities by students;
- the demand for, and the range of careers entered into by, physics graduates;
- the demand for, and supply of, teachers of physics in schools and colleges.

Delivery and Content

- the changing nature of post-16 education, and the differing pre-university educational experiences of all undergraduates, including mature students;
- the changing nature of undergraduate physics courses;
- the training of teachers of physics for schools and colleges;
- The Institute's requirements for accreditation of degrees and awarding of Chartered Physicist status;
- the impact of the Quality Assurance Agency on the delivery of physics undergraduate teaching.

Resources and Access

- the funding of, and resources for, teaching in university physics departments and the financial position of physics departments;
- the balance of public and personal funding for physics undergraduates;
- the scale, nature, diversity and distribution of undergraduate physics in the UK.

Methodology

Given the broad scope of the issues to be covered, it was immediately evident that the Inquiry would have to take a consultative approach to its deliberations. A series of regional events were organised through the early part of 2001 in Edinburgh, Warwick, London, Cardiff and York. Representatives from Northern Ireland were invited to the York Forum. It was the Inquiry's intention that every university in the UK should be invited to send a representative to a local forum, whether or not that institution offered a degree in physics. The Inquiry was particularly pleased to hear comment from several new universities without distinct physics departments. In addition, the forum events benefited greatly from the presence of current and recent undergraduates and of those associated with the teaching of physics in schools.

There was also an open meeting dedicated to the Inquiry at the Institute of Physics' 2001 Annual Congress in Brighton.

The Inquiry Secretariat also engaged in correspondence with, or arranged bilateral meetings with, several organisations with an interest in the issues facing the Inquiry.

In addition to meetings, the Inquiry undertook correspondence-based consultations, the results of which are summarised in Appendix IV. The following consultation exercises were undertaken:

- A mail-based survey was sent to over 100 likely employers of physicists, but as is frequently the case in employer consultations the response rate was low. In order to hear directly the views of employers of physicists, a special forum was held at the Institute in June 2001. This well-attended event greatly expanded the knowledge base of the Inquiry in the area of employer concerns.
- With the assistance of the Standing Conference of Physics Professors, the Institute circulated a questionnaire to the heads of all university physics departments. Responses were received from 26 departments, of which two were from the new university sector. Separately informative comments were received from the Open University.
- The Inquiry commissioned Survey-World.com to undertake a Web-based survey of current and recent physics undergraduates. 1096 responses were received to the undergraduate survey and 791 to the graduate questionnaire. As recommended by Survey-World.com, the key emerging findings and contentious issues were trialled with the readers of *Physics World* in the May 2001 issue. This yielded several written responses which greatly developed and clarified the issues raised by the initial survey.

In addition to meetings and written consultations, the Inquiry was informed by a dedicated effort to obtain and collate official statistics relating to physics higher education and teaching. A summary of these data is provided as an annex to this Report entitled *Statistics of Physics in UK Higher Education*.

It is the Inquiry's intention to publish Survey-World.com's report. It is planned that supporting material for the Inquiry will be placed on the Institute's Web site (www.iop.org).

The Inquiry Panel is most grateful to the Universities of Cardiff, Edinburgh, Warwick and York for hosting regional fora of the Inquiry. The Panel thanks Survey-World.com for the Web-based surveys of undergraduates and recent graduates. The Panel is also most grateful to the Standing Conference of Physics Professors for facilitating the survey of university physics departments and for arranging discussions which greatly assisted the Inquiry.

The Inquiry Panel is most grateful to Dr William Nuttall and Dr Iain Macpherson of the Institute of Physics who jointly provided the Secretariat to the Inquiry. The Panel also acknowledges the substantial assistance of Tajinder Panesor of the Institute who assembled the statistical data upon which the Inquiry relied. The Panel benefitted from valuable insights from many other Institute staff. Publication and dissemination of the Report has been made possible through the substantial efforts of the Public Affairs Department of the Institute and Mairi McLellan of Institute of Physics Publishing.

The Panel thanks Dr Sean McWhinnie of the Royal Society of Chemistry for statistical advice. The Panel thanks the Education Group of the Institute of Physics and Bob Lambourne of the Open University for useful discussions. The Panel is most grateful to Professor Paul Coleman, Dr John Crookes and Professor Gareth Jones for presentations made to the Panel during the course of the Inquiry. Professor Jones is further thanked for the paper on European Higher Education, included in this report as Appendix II.

The Panel cannot possibly thank by name all the numerous people whose efforts made possible the various elements of the Inquiry. The Panel is most grateful to all those who contributed to its work including those who attended regional fora or completed survey questionnaires, without such assistance the Inquiry would not have been possible.

II Physics Higher Education – the European Context

An edited version of a paper prepared by Professor Gareth Jones, Delegate for Europe of Imperial College, and provided for the information of the Inquiry Panel.

Radical changes are occurring in the pattern of university degrees across Europe. These changes started with the Sorbonne Declaration of May 1998, signed by the Ministers for HE of France, Germany, Italy and the UK, which called for a 'Harmonisation of the architecture of the European Higher Education system'. This was followed by the Bologna Declaration of June 1999, signed by the Ministers for HE of 29 European countries, which called for the creation of a 'European Higher Education Space' with a system of 'readable and comparable degrees'. An important meeting (Convention of European Higher Education Institutions) was held in Salamanca on 29/30 March 2001 to discuss progress in meeting the Bologna objectives and to prepare the universities' official input to the Prague meeting of Ministers, the next stage of the Sorbonne, Bologna sequence.

Underlying these declarations is an emphasis on mobility and employability within Europe and a wish to produce a system of degrees which is more attractive to students in Europe and world-wide. Thus, the internationalisation of HE is a driving force. Other driving forces are a wish to rectify some chronic problems of low completion rates and over-run of students' studies that are prevalent in several European countries.

The pattern chosen is a system of undergraduate and postgraduate degrees (a first and second cycle) with the sequence Bachelors (normally three years), followed by Masters (normally a further two years following an appropriate Bachelors), followed by a Doctorate (normally three years following an appropriate Masters). Thus, we have the 3, 5, 8 system. Graduates can leave the system at each of these break points with degrees which 'have value on the labour market'. The Bologna Declaration stated that first cycle degrees should be not less than three years in length and that 'access to the second cycle shall require successful completion of first cycle studies'. It is now accepted that Bachelors degrees can be three to four years long and Masters can be from one to two years long, but with a fairly strong presumption that the norm is five years to reach the Masters level. The alternative of measuring duration by ECTS credits rather than years brings no advantages for the UK.

The Bologna Declaration does not have the force of law but it is much more than a political statement. There is a clear commitment to implement the objectives coupled with an action plan to back up the process. Thus, laws on reform of HE incorporating the Bologna structure have been enacted in several countries. This has become known as 'the Bologna process'. During the last two years, a Bologna type degree structure has been introduced in several countries, notably Italy and Germany, and the creation of such a structure is underway in most European counties. This has not been without opposition, and in Germany most of the majorTechnisches Hochschulen and Universitaeten continue to offer the traditional 'Diplom' degree, which has been recognised as being at Masters level. Meanwhile, all Fachhochshulen have produced Bachelors and Masters programmes. A Masters level degree is regarded as the minimum for professional purposes in engineering and physics and for access to PhD courses, with a Bachelors being regarded as suitable for lower-status jobs or non-degree-specific jobs.

There are two particular issues arising from the Bologna Declaration that concern UK engineering and physical science. Both concern the 'anomalous' nature of 'undergraduate masters' awards in the UK:

(a) Can integrated courses reaching Masters level (e.g. MEng, MSci, MPhys, with no Bachelors en-route) be maintained and regarded as consistent with the Bologna principles? This is a Europe-wide issue and the case for their retention has been pressed strongly by European groups of engineering/science universities. At Salamanca this position was accepted (with some difficulty after opposition) and appeared in the final rapporteur's summary. However the statement referred to integrated five-year curricula. Moreover, the UK Minister has stated that Masters level awards, no matter how produced, should equate throughout Europe to second cycle degrees. If these degrees were split into a Bachelors and an MSc stage, some coherence and integration would be lost.

(b) Will MSci/MPhys awards be recognised as justifying their Masters label despite the fact that they are four years rather than five years long, or will they be regarded as an 'Advanced Bachelors' degree, as is being pressed in some quarters? This is an issue within the UK as well as internationally. The Quality Assurance Agency framework documents allow this but impose criteria concerning the amount of advanced content in the curricula and the extent to which it is related to current research results and generates MSc level competencies. Thus, international recognition of these degrees is endangered by any examples of MPhys degrees which do not reach a sufficiently high academic level.

Conclusions

The case for continuation of MSci/MPhys degrees as Masters level awards, despite their anomalous nature with respect to the Bologna Declaration, is close to being accepted, but there is a strong requirement to ensure that they truly reach Masters level. The alternative of splitting these courses into a Bachelors stage (with the award of the Bachelors after three years) followed by a Masters is academically feasible but brings difficulties for student funding. There may be advantage in adopting a system in which students at the end of a three-year course may decide to opt for a BSc degree at that stage or to stay on (subject to normal eligibility rules for access to MSc, i.e. second class honours) for a fourth year to gain the MPhys/MSci within an integrated programme. This would recognise the fact that many students do wish to enter the labour market after three years.

III Physics Higher Education Models

A paper prepared by Dr William Nuttall, Joint Secretary to the Inquiry. This paper was provided to the Panel in order to provoke wide-ranging thinking about higher education futures. The author is most grateful to all those who contributed insights and ideas on these matters during the course of the Inquiry.

Physics Higher Education in 2010

The intention behind the following text is to look ahead and to examine ways in which UK undergraduate scientific education might evolve in the coming decade. Following the Panel's clear support for diversity within UK higher education, the five models described below were developed in order to understand better the different paths that might be followed by various institutions. No one model is proposed as the future of scientific higher education as a whole. The diversity of physics provision in the UK might span all these models (and more) simultaneously. The models described are intentionally thought provoking and are not meant to be in any way prescriptive. They are entirely fictional and should not be regarded as necessarily representing the views of the Inquiry Panel.

Model A – Major International Research University

A physics department in this model has an annual intake of approximately 150 students arriving with, on average, 26 A-level points. All students have strong grades in both mathematics and physics. Entry for MPhys typically requires strong A-level scores in both subjects while entry to BSc programme requires, as a minimum, good grades in A-level mathematics and AS physics.

There are no part-time students in the physics department and a typical home student's family residence is 300 km from the university. The department has many overseas students, attracting 25% of its intake from the European Union and further afield. The university has publicly expressed an interest in achieving wholly merit-based and 'need-blind' access without regard to the applicant's nationality.

Of the graduating class, 70% achieve an MPhys degree and 30% a BSc. Drop-out is negligible and net transfers to other subjects correspond to around 8% of the physics intake.

The physics department is known for, and proud of, its internationally visible research, which consistently achieves the highest levels of evaluation and recognition. The MPhys and BSc Honours degrees are accredited by the Institute of Physics for Chartered Physicist status (CPhys).

Model B – Large Vocational University

One university following this model now graduates more students from science-based degrees each year than any other university in the UK; yet it has no 'physics department' and offers no 'physics degree'. The university employs 20 Chartered Physicists teaching its courses, including those entitled Environmental Monitoring, Instrumentation Sciences and Sports Science. 40% of its BSc Honours students in science study part-time and 70% have their family residence within 20 km of the university. Drop-out rates approach 20% and net transfers yield a further reduction of 10% of the entry cohort.

The university prides itself on matching the needs of employers (both locally and nationally); providing retraining for mature students in technology areas; and in providing a ladder of learning for disadvantaged students. There is little unemployment among graduates of the School of Applied Sciences. The university does not offer an MSci or MPhys qualification and only rarely awards the PhD degree.

The university is known for its degree franchising whereby further education colleges in the UK and overseas can admit students to its university degree courses.

Science graduates from the university are in particularly high demand since formerly technical and craft positions increasingly require graduate level skills. Much of the drive towards graduate recruitment has arisen from the increasing regulation and complexity of these occupations. Examples of occupations pursued by Model B institution graduates include registered gas installer, local authority air quality officer, leisure centre manager, silicon 'wafer-fab' specialist and aviation maintenance specialist.

Model C – Regional Centre of Excellence

Universities following this model tend to be proud of their long history and regional presence. University senior management firmly believe in the need for the university to have branded 'departments' in each of the core disciplines of traditional higher education.

The BSc Honours degree in physics is of central importance to several departments following this model. Entry is offered to students achieving reasonable grades in both mathematics and physics. The typical physics undergraduate entry cohort numbers 25 students. The vast majority of students live in university accommodation during their first year and almost all study full time. Drop-out rates are below 10% and net transfers account for a further 10% loss.

The physics department maintains economic viability through its 'hourglass profile'. Physics 101 is a required course for all (400) first-year students in the Faculty of Science and an optional course for students from several other faculties. Physics 101 represents a substantial teaching commitment for the physics department. If taken in isolation, the final-year BSc physics classes would certainly be uneconomic, as the student : staff ratios in these core physics modules are extremely small. Taken overall, however, the physics department has a healthy balance sheet with most income arising from its service teaching and research.

Physics research at the university is substantial and pervasive. Strong physics research groups exist not only within the physics department but also within related departments and faculties such as environmental science, chemistry, applied mathematics and electronic engineering. The university consciously aims to bring all researchers together in regular Physics Forum events hosted by the physics department. The university approaches the Research Assessment Exercise strategically, submitting researchers drawn from 14 departments to only nine RAE panels. While both first-year teaching and research represent substantial commitments for the department, the narrow neck of the 'hourglass profile' is represented by the small size of the physics BSc third-year class.

The university has had notable success in providing a range of optional final-year modules drawn from a very diverse range of university departments. Related to this success has been an increasingly popular option of a BSc physics course incorporating fully approved teacher training components.

Most universities following Model C strategies offer MPhys/MSci provision collaboratively with regional partners. One or two universities continue to offer free-standing MPhys/MSci courses, but these are appearing increasingly unsustainable, given the high costs per student. Several regionally isolated universities have modified their MPhys/MSci programmes to allow for novel provision based upon student mobility. In this structure,students remain registered at their home institution for the duration of their studies and receive an MPhys/MSci degree (accredited for Chartered Physicists status by the Institute of Physics) from the university of their initial enrolment. Students, however, spend one semester during the final year of their degree at another university within the 'MPhys Network' of ten Institutions. Central administrative arrangements are provided by an Institute of Physics secretariat on a three-year trial basis using a grant from the DfES and the Higher Education Funding Councils.

In a review undertaken in 2008, MPhys/MSci arrangements provided by regional collaboration and/or student mobility were judged to be as educationally rich as the provision on offer at the Model A institutions referred to earlier.

The BSc and MPhys physics degrees awarded by Model C institutions are accredited for Chartered Physicist status (CPhys) by the Institute of Physics.

Model D – Broadening Provision

Since 2002 the Institute of Physics has assisted the introduction of a new model BSc 'Physical Science' degree. This builds upon provision at some pioneering institutions and grew after the 2001 Inquiry into Undergraduate Physics in which the idea of a 'New Degree' had first been discussed at a national level.

The Physical Science degree is less mathematical in emphasis than the traditional BSc degree in physics. The new degrees are on offer in two institutions with a Model A profile where they run in parallel with conventional MPhys/MSci/BSc physics courses. Importantly, however, there has been significant growth in BSc Physical Science provision at universities with small physics departments and science faculties. Some university physics departments have strategically restructured and repositioned themselves so as to be major providers of the new qualifications. In the last two years three universities have closed their BSc physics programmes in order to concentrate on the Physical Science course, which had turned out to be more popular with the university's applicants.

The growth in Physical Science provision has been facilitated by a Central Curriculum Support Secretariat funded by the Funding Bodies and the Learning andTeaching Support Network. This centralised provision includes a dedicated Web site entitled *Physics First,* offering high-quality learning modules and teaching support materials directly to institutions. Plans are underway to broaden this provision so as to match more closely best practice from the emerging 'E -University' sector.

Model E – Distance Learning

During the last decade (2000 – 2010) Britain's leading distance learning university has gone from strength to strength, combining the greatest level of regional access, educational technology and communications expertise for an increasingly global presence. It has has faced increased competition from innovative British providers following Model D type strategies and international, principally American, institutions which have secured British and European accreditation for their innovative courses. Rarely, however, are these international entrants focusing their provision on physics and related subjects, as they prefer to attack more clearly vocational higher education markets.

Britain's leading Model E provider is increasingly proud of its distinguishing strengths and renowned high standards. From such thinking emerges a renewed emphasis on the core scientific disciplines (in part reminiscent of

Model C, discussed above). Flexibility of provision is maintained, as is the wide range of higher education qualifications that may be awarded from its modular courses. This range and flexibility remains one of the key attractions of the university for mature students and distance learners.

The university has consistently retained Institute of Physics accreditation for Chartered Physicist status for certain course combinations.

IV Community Consultation Summary Findings

Web Based Surveys of Undergraduates and Recent Graduates

From the start the Inquiry Panel resolved that it must hear directly the opinions of current undergraduates and of recent graduates. The Secretariat suggested that a Web-based tool should be used in order to obtain a large response rate. Following extensive scoping discussions, the contract for the surveys was placed with a consultancy firm Survey-World.com, which specialises in Web-driven computer databases.

The Inquiry was pleased that the survey managed to receive responses from approximately 10% of all physics undergraduates in the UK and from a sizeable number of recent graduates. Whilst students from 55 universities responded to the survey, approximately 20% were from Cambridge University. Survey-World.com rightly caution that the sampling used is not fully representative and was not probabilistically framed. For this reason principal and contentious findings were fed back to the wider physics community in an article in the May 2001 issue of *Physics World.*

The full text of Survey-World.com's report will be made available from the Institute's Web site.

The Inquiry is most grateful to all the current undergraduates and recent graduates who took the trouble to complete the questionnaires. Two prizes each of book tokens worth £50 were awarded at random, one to an undergraduate and one to a recent graduate.

The results of the surveys may be summarised as follows:

Undergraduates

- 1096 undergraduates from 55 UK universities responded to this survey.
- 70% of the undergraduate respondents were male.
- 61% of the respondents were enrolled for an MPhys / MSci.
- 87% of undergraduates believe their courses to be up-to-date and not to have too much laboratory work. About half believed the choice of final-year modules to be adequate.
- 82% agreed that the teaching of physics was good, with 61% and 68% respectively agreeing that school physics and mathematics had enabled them to tackle university physics with confidence.
- Significant numbers of undergraduates obtaining an A or B grade in mathematics and/or physics at A-level did not believe that school had prepared them for their university course.
- Some 54% of those who enrolled for physics were fascinated by aspects of the subject and this was the main motivator for their enrolling for physics at university.
- 86% of the respondents attend a university that is more than 20km from their homes.
- Students fund their studies by a variety of means, with student loans, support from guardians/parents and vacation work being cited most often.

Recent Graduates

- 791 graduates completed the questionnaire, of whom 72% were male.
- Most graduates were aged between 21 and 30 years, with approximately 40% having a postgraduate qualification.
- As was the case with undergraduates, the main motivator for enrolling for a physics degree was a fascination with aspects of physics.
- About one third reported no debt on graduation.
- 21% of graduate respondents had debts in excess of £5000 on graduation.
- About 40% of graduates reported earnings of less than £15000 p.a. (It is assumed that many of these individuals will be pursuing PhD studies.)
- Data handling and IT skills were cited as the skills most frequently used in the work place.

University Physics Departments

26 departments responded to the Inquiry's survey (see appendix I). Of these, 24 were from 'traditional' universities.

Two thirds of respondents reported static, or lessening, demand for undergraduate physics places. Those reporting a significant increase in demand suggested the following reasons: the introduction of joint honours degrees in mathematics and physics; the introduction of more general courses; improvement of open days; liaison with secondary schools; widening choice of degrees; more flexible entry; MPhys meetings aimed specifically at potential female applicants; better recruitment literature; and astrophysics courses.

The prevailing view of respondents was that the traditional physics course with a strong mathematics and physics requirement had to be maintained.

A quarter of the respondents supported the introduction of broader courses alongside traditional ones, where broader was understood to mean courses with more liberal demands on mathematics. One department mooted the introduction of a Foundation Degree. There was no certainty amongst respondents, however, that broader courses would find a market.

When asked about the attractiveness of physics courses to potential students, respondents were principally concerned that the lack of specialist physics teachers in schools led students to lose interest in the subject. They called on the Institute to act with the community to publicise the employability of physics graduates. Respondents felt there was a need to investigate why well-qualified students choose other subjects.

Departments reported increasing amounts of general skills teaching on their courses. Examples included working in teams; placement schemes; report writing; and project work. A number of respondents commented that they integrated this type of work into their physics teaching programme. In particular, skills like computer literacy, numeracy and problem solving were said to be a natural by-product of a physics education. One department was exploring the idea of hiring an outside consultancy to teach leadership and assertiveness skills.

Departments were asked to comment on the supply of graduates into the job market. Respondents were concerned that not enough of their graduates were entering the teaching profession. Additionally, respondents were concerned about a potential shortage of PhD students: respondents cited debt, low pay, status and a buoyant economy as reasons. Departments called on the Institute to provide funds to increase interaction with schools. Views were split on whether, in future, departments will be able to fill studentships and lectureships; many respondents said an increase in the student stipend would address the issue of PhD recruitment.

Respondents were asked to comment on whether they had obtained evidence of changes to the nature of entrants to courses. All departments monitored student performance carefully through course work and tutorials, as well as diagnostic testing; other respondents were considering the introduction of such tests.

Many respondents said that prior knowledge tests provided evidence of a change within the students' level of preparation. Many departments worried about the mathematics preparation of new entrants and had modified their courses to address this issue. Respondents commented on the absence of mathematics in A-level physics; they said that students find it hard to use their mathematics in a physics context. Several respondents were concerned about the lack of depth of the mathematics syllabuses and wished to address these deficiencies but without de-motivating the students.

Departments were asked if there were sectors of society from which students could increasingly be encouraged to study physics. Respondents cited women; mature students; students from ethnic minorities; students currently choosing mathematics and computer science courses; and students with mathematics, but not physics, at A-level.

Respondents also suggested that more departments should be teaching physics courses designed for arts majors and be teaching physics to medical students. There were also more general comments favouring expanding physics teaching into arts areas (e.g. physics and law), including at a modular level. However, there was no great expectation that initiatives in this direction would deliver significantly more students into physics departments.

Departments were asked to describe the changes to their courses over the last ten years. Respondents cited the introduction of the MPhys degree; modularisation; Quality Assurance Agency (QAA) quality review visits; more continuous assessment; more transferable skills teaching; less demanding BSc courses; transfer of higher-level material to later course years; broader courses, better suited to those whose career aim is not physics research; more emphasis on 'physics with' and joint degrees; and lower mathematical content, especially in the first year.

Departments were asked whether the introduction of the MPhys had proved beneficial: the majority of respondents concurred. They said that PhD students were now better prepared and, generally, graduates embarking on a teaching career were better prepared. Effectively, streaming enables teaching to a greater depth: departments could better judge the aptitude for research of potential PhD applicants. The four-year course helped maintain the level of the degree while also allowing for the teaching of transferable skills. Graduates also had greater maturity.

Respondents were concerned that the extra year's fees are deterring students from MPhys (and PhD) degrees. Respondents were also concerned about the increased teaching loads associated with the MPhys. However, the higher level of project work in the final year is seen as beneficial. A fear that the MPhys might undermine the BSc had not, as yet, been realised.

Departments were asked about their links with schools and teacher training establishments. Most departments did not have formal links with teacher training establishments; about one quarter of respondents said they had schemes whereby students could have contact with schools; many said it was not a priority for their students.

Departments were asked how much service teaching they did: approximately half responded that they provide some service teaching, although many of these said they did not teach significant amounts. Departments most likely to receive service teaching were chemistry, mathematics, engineering, medicine and life sciences. Many departments reported that the mathematics department taught some of the mathematics courses for them. Others imported teaching related to the 'minor' options.

Departments were asked how important it was for them to teach physics within a department explicitly labelled 'physics'.There was an unequivocal 'yes' from respondents, both staff and students; moreover, it is important to have a physics building.

Departments were asked about the perceived importance of the Institute's accreditation scheme. Many respondents were positive about the scheme: it was perceived as helpful to have an external validation of quality; it had also proved useful as preparation for the QAA subject review and been helpful for marketing the courses. There was talk of a need for flexibility and for more co-ordination with the QAA.

Departments were asked to comment on the impact of the QAA subject review: most were positive. This review stimulated better quality assurance, a tightening up on procedures and paperwork, increased reflection on course aims and the sharing of good practice. However, the workload on staff involved was too high – particularly for smaller departments.

Departments were asked whether physics departments stood to benefit from increased participation rates in higher education: a number said yes, although they worried about the ability of mature students and others to handle a traditional physics degree, and of departments to teach them. 'Physics is not for the less able' seems to be the message; less demanding courses would be more appropriate. No one felt that there would be a large increase from other sectors of society: one department commented that new courses should take into account the needs of employers.

Departments were asked about the consequences for physics of further departmental closures. Some view closure as inevitable, driving up standards and providing efficiency gains; others disagree and worry about lack of diversity in the system and lack of regional provision. It was argued by some that the research base would decrease, although teaching would be less affected; others worried about the marginalisation of the subject and the detrimental effect this could have on schools' perception of the subject.

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