IOP Institute of Physics

RCUK Review of UK Physics

Institute of Physics response to a Research Councils UK Review

A full list of the Institute's submissions to consultations and inquiries can be viewed at www.iop.org

23 May 2008

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Professor W A Wakeham
Chair of Review Panel
Research Councils UK
Polaris House
North Star Avenue
Swindon SN2 1ET

IOP Institute of Physics

Dear Professor Wakeham

RCUK Review of UK Physics

The Institute welcomes the opportunity to respond to the RCUK Review of UK Physics. The attached annex details our responses to the questions listed in the invitation to submit evidence.

If you need any further information on the points raised, please do not hesitate to contact me.

Yours sincerely

Professor Peter Main
Director, Education and Science

IOP Institute of Physics

RCUK Review of UK Physics

General information about the Learned Society

1. Please provide a description of the origins of the Institute of Physics and an overview of its present day functions.

The Institute of Physics is a scientific membership organisation devoted to increasing the understanding and application of physics. It has an extensive worldwide membership (currently over 34,000) and is a leading communicator of physics with all audiences from specialists through government to the general public. Its publishing company, IOP Publishing, is a world leader in scientific publishing and the electronic dissemination of physics.

a) The history of the Institute[1]

The present day Institute of Physics was formed in 1960 from the merger of the Physical Society of London, founded in 1874, and the Institute of Physics, founded in 1920.

The Physical Society was founded to provide a forum for the promotion and discussion of physical research. From its beginning, the society held open meetings and demonstrations and published its proceedings. The membership was broadly based, including eminent academics, schoolteachers and amateur scientists.

In the early part of the 20th century, the profession of 'physicist' emerged, partly as a result of the increased demand for scientists during World War I. In 1917, the Council of the Physical Society started to explore with the Faraday Society, the Optical Society and the Roentgen Society ways of improving the professional status of physicists. This culminated in the creation of the Institute of Physics under special licence from the Board of Trade in 1920. As with the Physical Society, dissemination was fundamental to the Institute, which began publication of the 'Journal of Scientific Instruments' in 1922. The annual 'Reports on Progress in Physics' began in 1934 and is still published today.

In 1952, in line with its role in creating and promoting the profession of physicist, the Institute began the 'Graduateship' course and examination, which ran until 1984 when the expansion of access to universities removed demand.

In 1960, the Physical Society and the Institute of Physics merged to create 'The Institute of Physics and the Physical Society' as a single organisation combining the learned society tradition of the Physical Society and the professional body tradition of the Institute of Physics. The grant of a Royal Charter in 1970 was the opportunity to shorten the name to 'The Institute of Physics'.

[1] www.iop.org/aboutus/The_Institute_of_Physics/History/page_1816.html

b) Present day functions of the Institute

The Institute's mission, currently set by its 2006-2010 strategic plan, is to: further the understanding of the physical world and its application for economic and social benefit; promote interest and participation in physics across society as a whole; and support and involve physicists throughout their education and careers.

The full spectrum of present day activities are best illustrated in the Institute's introductory brochure, 'Promoting physics, supporting physicists'[2]. A more detailed breakdown of the Institute's day-to-day activities can be found at www.iop.org/activity/index.html, which includes the following:

- Supporting Students
- Diversity
- Schools and Colleges
- Supporting Universities and Academics
- Resources for the Academic Community
- Business and Innovation
- Groups and Divisions
- Careers
- Professional Development
- Local Branches
- Engaging the Public
- Science Policy
- International relations
- Awards
- Support and Grants
- Sources of funding from the Institute of Physics.

2. Please detail how the Institute of Physics supports physics academics in the UK.

The Institute supports academic members in a number of ways:

- There is a well-established set of around 50 subject and professional groups. Most are concerned with specific subject areas of physics such as magnetism, particle physics, quantum gravity, etc. Many groups have a professional aspect around an area of common interest, for example, the Education and Higher Education Groups, and the Women in Physics Group. Each group is given an annual budget to organise scientific meetings, workshops, newsletters, etc.
- The Conference Office is a service offered free to groups to carry out the administrative duties involved with the organisation of meetings and conferences. Occasionally, where one of the groups has an interest, the Conference Office will take on the administrative organisation of a major international conference.
- The 'Research Student Conference Fund', currently £30,000 p.a., offers support to research students attending major international conferences.
- IOP Publishing is the largest publisher of physics journals in the world.
- The Institute's PR team issues press releases for papers published in IOP Publishing journals or presented at Institute conferences.

[2] www.iop.org/aboutus/The_Institute_of_Physics/Promoting%20physics,%20supporting%20physicists/file_26669.pdf

- The Institute hosts the ‘Standing Conference of Physics Professors’, which comprises the heads of all UK physics departments. It meets twice a year.
- The Institute hosts seminars on matters of interest to academics. Recent seminars have included discussions on the REF replacement for the RAE and the merger of PPARC and CCLRC.
- The ‘IOP on Campus’ scheme involves visits to physics departments around the UK in which Institute staff meet with students and staff at all levels, including departmental and university management.
- Regular meetings are held with senior figures in the research and funding councils promoting the views and interests of academics.
- Diversity good practice is promoted to departments. For example, the influential ‘Women in University Physics Departments’ site visit scheme has led to the development and implementation of the ‘JUNO Project’ and a guide to good practice in physics departments on dealing with disability will be distributed shortly.
- Several projects within the HEFCE-funded ‘Stimulating Physics’ programme assist academics directly. The new ‘Integrated Sciences’ degrees offer new routes into physics and the ‘One Voice for Physics’ project enables a coherent message to be sent to potential physics students.

3. Describe the support the Institute of Physics gives to academics in achieving economic impact and wider user engagement.

The Institute actively supports the exchange of knowledge between academia and industry.

The subject and professional groups provide forums for knowledge exchange between academic researchers and those working in industry. In addition, an extensive programme of subject-driven conferences and meetings provide opportunities for physics research to be presented to all audiences. These conferences cover a broad range of topics and often contain dedicated industrially-oriented sessions, such as the ‘Industry Technology Programme’ (ITP) at the Institute’s annual optics and photonics conference, ‘Photon’. The ITP includes sessions designed to be of particular interest to those in the optics industry and are organised in collaboration with industry bodies, promoting opportunities for technology transfer and collaborative research. Previous themes of the ITP have included ‘Innovative Industrial Laser Processing Technologies for Next Generation Manufacture’ (organised with the Association of Laser Users) and ‘Optoelectronic Chemical Sensing’ (organised with the UK Optoelectronic Chemical Sensing Network).

The Institute works closely with organisations that translate academic research into commercial products. For example, the Institute is the grant manager for the Photonics Knowledge Transfer Network. We are also involved in the events programme of the network, promoting its activities to our membership in both industry and academia. In addition, we acted as the press office for the Scottish University Physics Alliance Knowledge Transfer showcase in February 2008, highlighting the economic impact of research currently being conducted in Scottish universities.

The Institute engages directly with physics departments and surrounding businesses, facilitating contacts between the two groups through our network of national and regional officers. For example, the Midlands Branch of the Institute is currently piloting a scheme where the Branch acts as a matchmaker connecting small physics-based companies in the region and university physics departments. The aim is to help businesses overcome the initial contact barriers and form relationships with academics conducting relevant research with a view to collaboration. We further support those who wish to start or grow their business through targeted publications such as ‘Professional Briefs’[3], designed for those working in physics.

4. Please provide data on the make-up of your fellowship including, if possible, data on disciplinary affiliation, age and gender profile, and academic position.

i) Grade of membership

Hon. Fellow	37
Fellow	4464
Member	10056
Associate	9855
Student (UG)	7367
Affiliate	3258
TOTAL	35037

ii) Age

under 25	25.77%
25 - 30	10.21%
31 - 35	6.86%
36 - 40	5.96%
41 - 45	6.59%
46 - 50	5.55%
51 - 55	5.09%
56 - 60	5.02%
61 - 65	5.92%
over 65	17.60%
no data available	5.42%

iii) Gender

Grade	**Male**	**Female**
Hon. Fellow	94.59%	5.41%
Fellow	96.13%	3.87%
Member	88.72%	11.28%
Associate	77.39%	22.61%
Student (UG)	75.31%	24.69%
Affiliate	90.68%	9.32%

[3] www.iop.org/activity/business/Publications/Business_Support/file_4516.pdf

iv) Geographical location

The Institute has members in 118 countries.

Africa	0.59%
Asia	2.38%
Europe	7.33%
Middle East	0.35%
Oceania	1.78%
South America & Caribbean	0.38%
USA & Canada	4.34%
Ireland	5.14%
UK	77.71%

v) Employment sector*

Overall:

Services	12.1%
Industry	35.3%
Government	13.1%
Education	39.5%

Education breakdown:

University	84.3%
6th Form College	1.0%
School	11.5%
Further Education	0.7%
Other	2.5%

*Please note that this data is based on the 2007 Salary Survey, to which 1836 out of over 34,000 Institute members responded.

Input from the Learned Society

5. Please provide an overview of your society's perception of current strengths and weaknesses in UK physics, providing evidence where appropriate. Please explain how any weaknesses identified might be rectified.

The international reviews of UK physics and astronomy research undertaken in 2000 and 2005[4] provided an independent and robust analysis of the individual strengths and weaknesses of the main sub-disciplines of physics research. Due to the nature and quality of the reviews undertaken by panels of eminent international scientists, the Institute has no additional comments to make to the panels' findings.

However, the Institute's Science Board submitted a formal response[5] to the 2005 international review of physics, featuring independent responses from the physics community to comments made by the panel on specific sub-areas of research.

[4] www.iop.org/activity/policy/Projects/International_Review/index.html
[5] www.iop.org/activity/policy/Projects/International_Review/file_6364.pdf

6. Comment on the importance of physics in underpinning allied disciplines. Please provide examples of this.

The benchmark statement for physics degrees (2007)[6] from the Quality Assurance Agency states that: *"…Ideas and techniques from physics also drive developments in related disciplines, including chemistry, computing, engineering, materials science, mathematics, medicine, biophysics and the life sciences, meteorology, and statistics."*

Since physics deals with the fundamentals of matter and energy as well as being the origin of a great deal of instrumentation, it underpins a wide range of technologies and other scientific disciplines. The reductionist and mathematical approach of physics provides tools and techniques for many other subjects. The result is that physicists are increasingly working with members of other disciplines, including all of engineering, communications technologies, aerospace, the geosciences, chemistry, environmental sciences, biomedicine and the life sciences. In some cases, the contribution is at a fundamental level, such as the provision of atomic clocks for GPS systems, or scanning probe microscopes in pharmacy and materials science. In others, it will be more applied, such as the radioactive dating techniques used in archaeology, or the imaging processes in art history.

A good example of the underpinning and innovative nature of physics can be found in the energy sector. First, many highly-skilled, numerate people working in a wide variety of roles in the energy sector have an educational background in physics. The 2007 Salary Survey showed that physicists are employed in the petrochemicals, oil and nuclear fuel processing industries. Second, it is a fundamental physics mechanism, i.e. Faraday's law of induction, which has allowed the construction of transformers, inductors, and many forms of electrical generators. Third, present-day physics research is in the vanguard of fundamental and innovative developments into more efficient, low-carbon, electricity generation technologies. For instance, physicists have been developing and manipulating leading-edge materials, such as crystalline silicon and other semiconductors, such as gallium arsenide, to develop more efficient, cheaper photovoltaic devices. In addition, both nuclear fission and fusion technologies rely heavily on physics and physicists.

Another important example of an underpinning technique was the development of nuclear magnetic resonance (NMR). NMR, as its name suggests, involves resonant precessional motion of nuclei in a magnetic field. Its understanding requires an appreciation of quantum mechanics but its application is widespread. By studying the peaks of NMR spectra, skilled chemists can determine the structure of many compounds. In addition, NMR forms the basis for magnetic resonance imaging (MRI), the most important modern medical imaging technique. Similar remarks could apply to the development of the laser, also important for chemists, engineers and medical applications.

In fact, the role of physics in underpinning modern medical techniques is a huge area in its own right. Virtually all the imaging techniques (X-rays, MRI, EEG, MMG, PET scanners, ultrasound, infra-red, terahertz, optical probes) are underpinned by physics and a range of treatment techniques, particularly those involving lasers, are also reliant on physics. Even theoretical physics is playing a part, aiding the understanding of the operation of the ear and arrhythmic behaviour of the heart.

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[6] www.qaa.ac.uk/academicinfrastructure/benchmark/statements/Physics08.asp
[10] http://research.nottingham.ac.uk/NewsReviews/newsDisplay.aspx?id=464

Other examples include the development of synchrotron and neutron sources for materials, physics, biological, biochemical and chemical research. These major engineering projects have been driven by innovations in particle beam physics, detector physics, novel instrumentation and novel approaches to measurement, all of which have been developed by trained physicists, who also provide the theoretical basis that underpins these disciplines.

In summary, physics underpins other disciplines via:

- instrumentation which is routinely used by people from cognate disciplines, such as electron microscopes, scanning probe microscopy, SQUIDS, magnetometers, photon detectors, particle beams, light sources, sensors (e.g. ultrasound, thermal), etc.;
- techniques used by other disciplines: NMR, spectroscopy (e.g. mass spectrometry, optical, infra red, etc.), radioactive dating, radioactive tracing, and various forms of light manipulation, etc.; and
- the development of technologies such as nuclear fusion, quantum information, atomic beams, photonic materials, low dimensional structures, etc.

7. Comment on the willingness of the discipline to work in collaboration with other disciplines (interdisciplinarity). Please provide examples of this.

Physicists have always been willing to collaborate with colleagues in other disciplines, and some examples are described below. In the future, it is clear that physics, in collaboration with other disciplines, will continue to make vital contributions to the major problems of our age, such as improvements in energy generation, energy efficiency, public transport, crime prevention and the quality of life of an increasing ageing population.

Many of the current demands on scientists and engineers are highly interdisciplinary. Problems ranging from climate change to drug delivery require increasingly flexible approaches. Physicists have much to contribute to multi-disciplinary teams addressing such problems. For example, 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. The interface between physics and chemistry has also recently led to major developments, including nanotechnology, energy generation and efficiency, atmospheric research, surface science, smart materials and novel plastics.

Numerous examples of interdisciplinary collaborations are illustrated in the departmental responses to the Review. For instance, at the University of Leicester, there are: joint projects with biology and medical sciences, using detectors and techniques developed for astronomy and planetary science in medical applications; with engineering on components and materials for space applications; with chemistry on forensic techniques; with geology on planetary research; with geology, geography and chemistry on Earth observation science; and with mathematics and engineering on various computational problems. At the University of Manchester, the nonlinear dynamics research group established a new Centre for Nonlinear Dynamics in collaboration with members of the School of Mathematics.

A striking indicator of the enthusiasm of physicists for interdisciplinary activity is that the representatives from the former EPSRC Physics Programme on many occasions reported that only half of the research funds that EPSRC puts into physics departments came through its Physics Programme (49%); the other half was from a wide range of other programmes, such as Materials (15%), ICT (8%), Chemistry (3%), Engineering (3%), etc.

The research councils have recognised the increasing interdisciplinary nature of physics research. EPSRC recently embarked on its 2008-09 Cross-Disciplinary Interface programme, which will fund research at the interface between physics, the life sciences and complexity science, which itself is driven by physicists and mathematicians. In April, RCUK launched the new Institute of Biophysics, Imaging and Optical Science (IBIOS)[10], with grants from EPSRC, RCUK, the European Union, the Wellcome Trust, BBSRC, GlaxoSmithKline and Roche. The IBIOS, based at the University of Nottingham, will bring together engineers, physicists, biologists and chemists.

Over recent years, numerous university-based Interdisciplinary Research Collaborations[11] have been set-up nationwide, where physicists are making integral contributions to projects in collaboration with academics from materials, mathematics, computer science, biochemistry, chemistry, earth sciences, engineering, biology, electronics and computer science, and electronics and electrical engineering departments in the following projects:

- Quantum Information Processing
- Bionanotechnology
- iMIAS – From Medical Images and Signals to Clinical Information
- Superconductivity
- Biomedical materials
- Nanotechnology
- Polymers.

For some sub-areas, involving more fundamental research, such as particle physics, collaborations with other disciplines, while strong, tend to be either using state of the art engineering and computing to build apparatus and carry out experiments, or spin-outs of the instrumentation. For example, synchrotrons, which were originally developed by Luis Walter Alvarez to study high-energy particle physics, form the underlying technology for the Diamond Light Source, which will be used to probe the structure and properties of many types of materials and complex structures like proteins.

One of the areas to benefit most from the different technologies developed for particle physics has been medical physics. As examples, in this field, linear accelerators are used to administer radiation therapy in hospitals, while positron emission tomography (PET) offers a powerful diagnostic tool. Synchrotron radiation was first discovered at the high-energy accelerators used for particle physics experiments. Today, it is an extremely useful tool in many areas of research, both pure and applied: medical imaging; environmental science; materials science and engineering; surface chemistry; biotechnology; and the manufacture of advanced microchips. The scientific uses of synchrotron radiation include research into haemoglobin, and it has been important in the quest to find a cure for Lou Gehrig's disease and a vaccine for the AIDS virus.

[11] www.epsrc.ac.uk/ResearchFunding/Opportunities/Capacity/IRCs/default.htm

8. In the long term, please comment on the challenges facing the discipline, and how these might be addressed.

To answer this question, one first needs to consider what the discipline is. Attempts to define physics in terms of content tend to be unsatisfactory, leading to physics being the study of everything. Rather, it is more a way of thinking, a reductionist view of the world, where phenomena can be understood in terms of a relatively small number of physical laws. In practice, the limits to the subject are either due to complexity, where a system or phenomenon is so complex, its understanding requires unavailable computational and mathematical power, or due to the arbitrary convention that, when physics is applied to a particular area, it tends to be defined as being part of that area. This definition of physics implies that the boundaries of physics are expanding all the time, which is indeed the case: consider the development of the understanding of non-linear systems, which now allows physicists to develop models of human hearing and financial markets.

If we accept the definition of physics as a way of approaching problems, with great flexibility and power, then it is clear that this way of thinking, while not quite absent in other disciplines, is concentrated heavily in physics departments. It is important, therefore, that like-minded people are able to work together, to keep the discipline alive, and to ensure future generations of graduates who 'think like physicists'.

In this context, there are several challenges for physics. One is undoubtedly the strong dependence on research council funding (which is discussed in more detail in response to question 11). While government ministers continue to assert in public their support for fundamental science, funding trends and more private discussions indicate an inexorable shift to a more accountable funding regime, in which the economic impact of the research has to be more visible on a shorter timescale. The challenge for physics, therefore, is to accommodate a more application focused approach, which would also improve funding stability, while preserving the essence of the subject. To turn physics departments into quasi-engineering departments would be an error; it is *essential* to preserve the critical mass of physicists as defined above.

In a similar vein, there is a major tendency in universities to move towards interdisciplinary centres. Often these are in parallel with, or even embedded in, conventional departments although some stand alone. Undoubtedly, physicists will continue to play a major part in centres of this type, but the challenge is for that involvement to be used to reinforce the health of the discipline and not just another example of physicists plying their trade in other areas. The following examples will help to understand the issue. At the University of East Anglia, there is a very strong interdisciplinary effort in environmental science, involving dozens of physicists but there is no physics department and no physics degree. Similarly, at the University of Reading, the Meteorology Department is one of the strongest in the country with many physicists (and Institute members); the University of Reading closed its physics department last year, although the university claims now to employ more physicists than ever. As a counter example, the MRI Centre at the University of Nottingham has remained part of the School of Physics and Astronomy, despite involving staff from all over the campus. That has enabled the School to maintain a broad funding base, which includes charities and the MRC; it is also able to offer courses in medical physics. Interestingly, and unusually for a physics department, the MRI Centre has two staff members and several research assistants whose first degrees are not in physics. Had the university chosen to float the MRI Centre as an independent unit, physics and astronomy would have been very much weaker.

A further challenge to the subject continues to be the fall in numbers studying physics post-16. A-level entries in physics have fallen by around 35% in the last 15 years, at a time when the cohort has been growing. There is a similar effect in Scotland although less pronounced. The Institute, both independently and with government, is working hard to recover lost ground and there are some indications of a recent turn around. However, the most serious problem remains: the dramatic shortage of specialist physics teachers. We estimate a shortage of between 5000-8000 physics teachers, although the shortage is hidden because, until very recently, government figures have referred to *science* teachers, ignoring the fact that much of physics pre-16 is being taught by biologists. Considerable progress has been made over the last two years but it is important that the pressure is maintained to increase the numbers of specialist physics teachers.

Perhaps surprisingly in the light of the falling A-level numbers and the closures/mergers of physics departments (over 20 since 1997), numbers entering physics degree programmes have been stable at around the 3000 level over the last 15 years. However, the percentage of the population entering university has increased dramatically in this period, so the fraction of university students that study physics has fallen by around 40%. Nevertheless, the relative stability of physics entries with an apparently shrinking pool of potential applicants indicates that the appeal of the subject to a certain type of student is robust. Indeed, the latest UCAS figures show an increase (around 9%) in the number of entrants. Surveys indicate that the areas of physics that enthuse this hard core tend to be the pure elements (i.e. astronomy and particle physics) that create the sense of wonder. It is a major challenge for physics to adapt its appeal to encourage more students with an interest in its application while not alienating its traditional constituency.

It is worth commenting that physics departments tend to be very protective of the standard in their subject and it is no exaggeration to say that there is now a major mismatch between the actual skills and knowledge of students entering courses and the expectations of the academics, which are frequently based on the A-levels (or Scottish equivalents) that were current 20 years ago. This is in the context of physics being measured as the hardest A-level[12].

Another feature of physics undergraduates is that the vast majority of them study in research-led universities. Of the 46 departments offering physics degrees in the UK, 10 of them provide almost half the FTEs and very few students indeed are based in the post-1992 universities. Consequently, physics is perceived as being an elite subject, a point of view corroborated by its entry requirement of two specific (and difficult) A-levels, i.e. physics and mathematics. With a few exceptions, departments have been reluctant to offer courses that are not traditional physics degrees. Consequently, one of the major access issues in physics is socio-economic class; the vast majority of physics students come from middle class schools where students study the requisite A-levels. The Institute is working with HEFCE in its ‘Stimulating Physics’ programme[13] to introduce a new physics-based degree, ‘Integrated Sciences’[14], to cater for students who cannot enter a conventional programme; but there are substantial barriers.

Finally, the other access challenge for physics is the gender balance. Only around 20% of physics students are female. Encouragingly, following graduation, the continuing participation of women in physics is rather better than in most other

[12] Relative difficulty of examinations in different disciplines. A report for SCORE by the University of Durham; 2008.
[13] www.stimulatingphysics.org
[14] www.integratedsciences.org.uk

subjects; for example, the percentage of females among the new academic appointments is almost the same as for the graduates. So, the major problem occurs at the transition from GCSE to A-level; the Institute is working hard on these issues, in collaboration with the government, and there are indications in the most recent figures for AS and A2 physics that the number of girls is increasing faster than for boys.

9. Is the current provision of Physics research facilities suitable for sustaining the discipline in the long term? If not, what actions should be taken?

Overall, the current provision of research facilities is suitable and funding has until now been adequate to provide and update the range of facilities critical to maintain and enhance the UK's position in physics research. However, departments have been shaken by the recent STFC funding shortfall, which many of them feel has jeopardised this position.

Physicists make use of a wide range of local, national (i.e. central), and international facilities for their research. International facilities such as CERN, ESRF, ISOLDE, DESY, SLAC, TRIUMF, VLT, etc., are used on a regular basis. Nationally, facilities at the STFC-run campuses (Daresbury, RAL and ATC) are used to support research efforts in particle physics, astronomy, nuclear physics and condensed matter physics, in addition to many other sub-areas of the discipline.

Many departments have a healthy balance between local and national/international facilities. Generally, facilities are internationally competitive and, in some cases, world-leading. However, major concerns surround the impact that the STFC funding problem will have on investment in necessary upgrades and future projects.

For the longer term, the recent STFC consultation on the Large Facilities Roadmap for 2007 sought input on the balance of the listed facilities-related projects. Overall, the Institute responded[15] by stating that, "*…there is a reasonable balance in the Roadmap, which has included a number of important large projects for particle physics, nuclear physics, astrophysics, astronomy, and other important areas of physics research. All of these facilities have strong UK and international involvement and are of a high priority*." However, some concern was expressed about the omission of space-based facilities in the Roadmap, and the STFC's decision to withdraw from the International Linear Collider, which we urged should remain listed as a future priority. Similarly, no logical reason has been given to justify the cessation of the ground-based solar-terrestrial programme, which involves challenging problems in plasma physics, which is an important area for fusion research.

A number of facilities were listed as future priorities, but there are two in particular that the Institute wishes to focus on here which will be important in the long term:

<u>Nuclear physics facilities</u>: Over the last decade, the UK has not had good access to facilities for nuclear physics. The 2005 international review of physics stated that, "*Having opted to forego onshore facilities, it is now incumbent on the UK to provide the means to pursue forefront research elsewhere*." Furthermore, concern was expressed concerning UK participation in major offshore nuclear facilities, such as the Facility for Antiproton and Ion Research (FAIR) project. The review recommended an arrangement along the lines of CERN or ILL in order to confer a status and influence that small nuclear physics groups cannot attain. The FAIR

[15] www.iop.org/activity/Informing%20Policy/Consultation%20Responses/Research/page_2981.html

project will be an important facility up to and beyond 2020, and it is important that the UK invests and participates at a significant level.

Next generation neutron source: Europe currently hosts the world's premier neutron scattering sources (ISIS and ILL) and has the largest, most experienced and broadest-based community of neutron beam users. However, Europe faces the likelihood of a ‘neutron drought’ as a result of the continuing expansion of the multi-disciplinary users, alongside the progressive and inevitable closure of ageing neutron research reactors. In addition, a serious challenge to European scientific and technical dominance in the field of neutron scattering has been mounted by the development of neutron facilities in both the USA (the Spallation Neutron Source) and Japan (the Japan Proton Accelerator Research Complex). The action being taken by the US and Japan is in full accord with the explicit recommendations of the Neutron Sources Working Group – OECD Megascience Forum report, which recommended that first class neutron sources should be upgraded, and that a new third generation MW spallation source should be constructed in each of the North American, Asian and European regions. Therefore, the UK should consider seriously making a political and financial commitment to host a third generation MW neutron-spallation source in the UK, i.e. the European Spallation Source.

There is a major issue concerning infrastructure. Much of physics relies on facilities, some of which are necessarily international (CERN, etc.) or national (Diamond, etc.); however, there are also smaller scale facilities, for example in fabrication, microscopy, atomic beams, etc., which are commonly housed in a single university with access for partners. While STFC looks after the first two categories, there is a need to ensure that there is clarity for the future funding of the third. One possible route is via regional collaborations, particularly to avoid some of the problems of the early rounds of the Science Research Investment Fund (SRIF) where comparable facilities were developed in several universities at the same time. In recent years, SRIF has had a major, positive impact on physics departments. At present, there is some confusion as to what will happen in the long term. There needs to be urgent clarification of (i) the future of dedicated infrastructure funding, and (ii) the role of FEC in funding local and regional infrastructure. If FEC *is* supposed to be playing a major role in this respect, universities need to be made aware of that fact very quickly and should be working at a strategic level with both research and funding councils.

In terms of future priorities, the underfunding for the operation of large facilities is a major concern. In the case of the Diamond Light Source and the ISIS Second Target Station, there were sufficient funds available to cover the costs of constructing new facilities and for essential upgrades, but not to cover operational costs. As a matter of course, the research councils should include these costs when planning new facilities or upgrades and to set aside in their forward planning the appropriate running costs. We wholeheartedly concur with the 2005 international review of physics that all future investments should be carefully balanced with national funding for the exploitation of the opportunities provided by these facilities.

10. Do you feel that the current training environment at all levels in physics departments is adequate to provide the skills and leadership needed in future?

Although there are different issues at different levels, there are themes that run through them all, notably the international dimension. Physics is an international subject, possibly more so than any other. Consequently, the skills and leadership need to be relevant in an international as well as a national context.

A common complaint from universities is that the incoming students have poor mathematical skills, despite their generally good A-level (or equivalent) scores. Typically, only entrants with experience of further mathematics are completely comfortable with the standard expected although that is more likely to be due to the extra practice than the higher knowledge base. Undoubtedly, a major step forward would be the restoration of relevant mathematics, such as calculus, to A-level physics syllabi. Generally, international comparisons indicate that our students operate at a lower level of mathematical sophistication than most other developed countries, although they do compensate with greater practical experience and a higher level of transferable skills.

Physics has two mainstream degrees: the traditional 3-year (4 in Scotland) BSc; and the 4-year (5 in Scotland) integrated masters MPhys (or MSci). Within each category, there are variations, including many programmes with a year spent abroad or in a work placement. There are also a variety of ‘Physics with’ combinations that couple mainstream physics with other areas of study; the most popular is astronomy, but there are also medical physics, applied physics, etc., as well as traditional joint honours courses.

The MPhys is the degree recommended for the professional physicist. It was introduced for two reasons. First, it had become clear that departments were cramming more and more new material into their courses without taking much out. Second, there was an increasing need to introduce more skills, such as ICT and communication, into the curriculum. The MPhys, generally, has been a great success and the final year gives genuine added value. Most observers see graduates of the integrated masters as superior to those from 1-year stand alone MScs. The BSc remains as an excellent first degree, comparable to any on campus.

With the introduction of top-up fees in England, there was a fear that the longer, integrated masters programmes would be perceived as too expensive. Fortunately, although it is still relatively early days, the MPhys degrees are still popular. However, there does need to be careful monitoring of the effect of graduate debt on postgraduate recruitment, particularly in light of the forthcoming review of top-up fees.

The Bologna Process has been an ongoing concern. Within the UK, although it is virtually certain that the Quality Assurance Agency will announce that the integrated masters programmes are consistent with the Bologna Agreement, there are widespread concerns that other major European nations will not accept them as such. Partly as a result of these fears, a number of English departments are contemplating the introduction of 3 + 2 year integrated masters. In Scotland, the situation is more complex as the MPhys is 5 years long and has already been presented as consistent with Bologna, but, in a UK context, it is also deemed to be at the same level as the English MPhys.

Leaving aside Scotland for the moment, it is difficult to see how a parallel system of 4- and 5-year integrated masters could work sensibly in England. In addition, the community is split on the desirability of the longer course. While accepting that it will increase competitiveness with the rest of Europe, some academics believe it would lead to an increased teaching load for the same number of FTEs and also fear the discouraging effect of top-up fees. It is fair to say that there is still considerable confusion on the best way forward in a Bologna context and, in the absence of any lead from government or its agencies, over the next year or so, the Institute will be working with departments to find a consistent approach.

As a final point on undergraduate training, the widespread introduction of modular degrees has done physics no favours. As an essentially linear, coherent subject, it does not yield easily to being split into small, independently examined, chunks. Its subtle concepts also require time to be absorbed and the tendency to examine modules soon after their completion has led to a superficiality of learning. There is perhaps a need to be more imaginative in assessment.

Of all subjects, physics has one of the highest rates of continuation of education at the postgraduate level. Many physics graduates choose to study in other areas, such as meteorology, environmental science, engineering, etc. The increase in stipends, thanks to the Roberts Review, and the extra flexibility introduced by the doctoral training accounts has led to a considerable improvement in the lot of postgraduate students in recent years. Generally, physics has a high PhD completion rate and doctoral graduates have good career prospects outside academia. It is worth noting that, because the more exotic, leading-edge areas of physics often attract the most able postgraduate students, PhD graduates from these areas are often in the highest demand from employers.

In the international context, however, there is a general feeling that UK PhD graduates are between one and two years behind their counterparts in other major industrialised countries. While much of the evidence for this is anecdotal, in the last 5–10 years there has been an ongoing and dramatic shift towards the employment of overseas research assistants (RAs) instead of those trained in the UK. This shift has almost certainly improved the quality of UK research but it does raise some concerns about future leadership in the UK if these people choose not to stay after completing their projects.

In general, RAs have not been treated well in university departments. The Institute's own 'Women in University Physics Departments'[16] site visit scheme highlighted many of the problems, which included very poor provision for career guidance. It is hoped that initiatives such as our own 'JUNO Project'[17] and the revised RCUK Research Careers Concordat will contribute to major improvements. One area that has been very successful has been the various research fellowships offered by the Royal Society, the research councils, etc., as well as the fellowships that emerged following the recommendations of the Roberts Review. These have given high-quality researchers a kick-start to their career, allowing them to spend several years researching before becoming involved in teaching and administration. Unfortunately, as these Fellows have been popular recruits for permanent positions, not least due to their personal funding, other RAs have suffered diminished prospects. While, in one sense, this is inevitable given the few academic jobs available, it is nonetheless the case that some RAs working on long-term projects are employed on a series of short-term contracts; there is a need to develop a permanent career path that recognises their vital contribution. For other RAs that perhaps are less suitable for research, there is a need for better, disinterested careers advice.

Almost a half of new staff appointments in the last few years have been overseas physicists who have not been through the UK educational system. This situation undoubtedly reflects the high quality of UK physics as well as the flexible, meritocratic appointments procedure, which is not reproduced in all European countries. The appointments also probably raise the standard of research. However, there are potentially devastating consequences on the ambitions of young UK scientists. The international flavour of departments in part reflects the global

[16] www.iop.org/activity/diversity/Gender/Diversity_and_academia/University_site_visits/page_25130.html
[17] www.iop.org/activity/diversity/Publications/file_25741.pdf

character of the subject but there is evidence that the influx of overseas physicists is not matched by a corresponding rise in the number of UK nationals obtaining posts in other countries. Therefore, one is drawn to questioning whether, in general, the UK system is producing PhD graduates at a level competitive with those from other countries. It is essential that this issue is addressed before the academic career prospects of UK-educated PhD graduates diminish to the point of affecting recruitment of postgraduate students.

The research councils, EPSRC in particular, have taken care to encourage academics early in their careers, with specific programmes for those who are making their first applications. However, STFC tends to fund large research teams and even EPSRC is indicating that it would like to fund larger programmes over longer time periods. This approach is probably sensible but it does make it much more difficult for new researchers to make an impact and to develop a portfolio of grants to build up a reputation. This concern is exacerbated by the peculiar arrangement whereby the principal investigator (PI), and only the PI, can claim his or her salary on a proposal. This is not yet a problem but there needs to be an active awareness of the issue. The Institute would recommend that no salaries should be allowed on grant applications and that the notion of the PI should be revisited, perhaps to allow a number of PIs, with one administrative contact who could take on the obligations of the current PI.

11. Do you feel the current funding structure for UK Physics is effective in supporting the discipline as a whole and in fostering interdisciplinarity? If not how could it be improved?

The funding of university physics departments has been a controversial issue for over 15 years, during which time more than a third of physics departments have disappeared due to either merger or closure. A number of factors have contributed to these closures, not least the abolition of the binary divide, which led to a change of mission for many of the former polytechnics, plunging them into direct competition with the more research-led universities. The subsequent introduction of the RAE then sounded the death knell for many of these departments. Physics stands out in RAE terms as having virtually no tail of departments with research grades below the 4 rating. Another effect of the RAE, which is mentioned elsewhere, has been to 'purify' physics: many of the departments that closed (Brunel, Bradford, Aston, etc.) had a strong applied flavour.

Another major factor that was instrumental in causing closures was the general decrease in the unit of resource in the 1990s. Contrary to popular belief, the number of entrants to physics degrees has not altered greatly over the last twenty years. However, the fall in the unit of resource encouraged the larger, more popular, departments to take increasing numbers of students, squeezing the smaller ones, making many of them financially unviable. Exacerbating this effect, it is a well-accepted view that the HEFCE banding profile for funding undergraduate teaching tends to undervalue physics; in short, the funding appears to be around 20% too low (see 'Study of the Finances of Physics Departments in English Universities')[18].

Recognising this issue and partly in response to the closures, HEFCE announced an extra £75 million over three years to support the teaching of students in certain high-cost subjects, including physics. This amounted roughly to an extra £1,000+ for each FTE, an increase of around 20%. Prior to this extra money being available, unpublished and informal Institute surveys indicated that the majority of departments

[18] www.iop.org/activity/policy/Publications/file_21216.pdf

were running at a loss according to their university financial models, so the extra funding was certainly well received. However, the money is due to stop at the end of next academic year and, although HEFCE has made encouraging noises about the outcome of its TRAC teaching project, it is clear that a reversion to the previous funding model would have serious consequences.

Currently, UK physics research is heavily dependent on research council support, although physicists have been particularly successful in attracting European funding (which is discussed further below). With a few exceptions, income from business and charities tends to be very low. This concentration of funding has been driven by the notion, reinforced by successive RAEs, that the best physics is concerned with increasing the level of fundamental knowledge and that, when the physics is ripe for application and exploitation, the process is carried out elsewhere, either in another department or in a spin-out company. Although this state of affairs gives some cause for concern, it does have one very positive side for physics. Due to the heavy emphasis on research council income, physics departments have benefited more than most from the introduction of FEC. Some universities have chosen to pass some or all FEC elements directly to the departments, which has left them rather better off than they have ever been in the past.

The introduction of FEC does lead to some concerns. It appears that many universities do not have a clear plan as to how the FEC will be used to support future infrastructure demands. There is the undesirable possibility that many departments will use the windfall to support growth in non-capital items, principally new staff, while not paying sufficient attention to their future infrastructure needs. This matter needs urgent attention before the FEC funding element becomes locked into university models.

Recent changes in departmental profiles have led to a higher level of research in astronomy and, to a lesser extent, particle physics at the expense of other areas of physics. There have been two strong drivers at play. First, both areas are seen as being attractive to potential students and, in the case of astronomy, more appealing to female students. The second driver is that the majority of physics funded by EPSRC requires in-house equipment and dedicated infrastructure, which means that the establishment of groups in these areas generally requires a large financial investment and the appointment of several staff. In contrast, in some elements of astronomy and particle physics, for example theory, phenomenology and observational astronomy, there are few infrastructure costs since the majority of the equipment is based in international locations. While it would be questionable to say that this shift to astronomy and particle physics has been a bad thing, since it may have helped maintain undergraduate numbers and enriched their experience, it has undoubtedly put a larger strain on PPARC and now STFC funding. In addition, there are around half a dozen departments with more than three-quarters of their research funding supplied by STFC.

STFC itself has not had a happy honeymoon following the merger between CCLRC and PPARC last year. The two Councils were poles apart in terms of research culture and, without revisiting the recent controversy, it does appear that there have been substantial management issues in dealing with the merger. For the future, there are two particular issues that need to be resolved. First, many of the facilities within STFC are useful to a broad range of engineers and scientists, most of whom receive their principal grant funding from other research councils. It is neither fair nor sensible for any funding problems in these areas to affect directly the exploitation funding for astronomers, nuclear and particle physicists. While not wishing to return to the bureaucratic and unpopular ticket system, it would seem sensible that the funding to operate these facilities should be supplied by the relevant research councils, probably at a broad brush level, so that any overspends, etc., are paid for by the right people.

The second issue concerning STFC is the balance between capital investment and the exploitation of the resource. One issue that was strongly debated at the establishment of STFC was whether the new council should retain the grant awarding facility provided by PPARC; following the recent controversy, some people have suggested that the grants should move to EPSRC. However, this would certainly run the risk of separating decisions about the facilities from their exploitation, and EPSRC would have to account for the different timescales related to current EPSRC and former PPARC science, and also the difference in the nature of research collaborations. Perhaps the best way forward would be that, when the decision is made to create or subscribe to a new facility, there might be an allocation of exploitation resources at the same time. This approach would also encourage tighter planning. Annual reviews of usage, etc., could be built into such a system.

With so much publicity concerning the problems with STFC funding, the projected cuts in the responsive mode (now called the Essential Platform) funding from EPSRC and, to a lesser extent, the disappearance of the dedicated physics programme, has been discussed much less extensively. However, it has led to considerable concern in physics departments. As the most fundamental of the sciences, physics flourishes best in the responsive mode, where it is the quality of the research that matters rather than its relevance to a directed programme. With projected cuts of 15% and 25% in the Essential Platform and STFC funding, respectively, there is likely to be a heavy strain on the funding of high-quality, investigator-driven research. Physics departments appear in line to bear the brunt of that strain.

There is a tendency to think of interdisciplinarity as a virtue in its own right instead of a route to solving certain problems. What should be important is the quality of the science overall. Having said that, physics does underpin a great deal of science and engineering and it is important to investigate what barriers there are to interdisciplinarity. The 2005 international review of physics commented on interdisciplinarity (section 3.6.5), reporting that most activity of this type appeared to be carried out in departments other than physics, even though much of it was driven by physics. A major advantage of establishing more interdisciplinary research in physics departments would be a broadening of the funding base and the consequent increase in stability.

There are two specific barriers to interdisciplinary activity, in addition to the normal cultural differences between disciplines. The first is that the role of physics is often to provide instrumentation or to underpin research in other areas. Consequently, the physics employed in such collaborations is often not leading edge in physics terms. Therefore, in RAE terms it is not considered high-quality and tends to be driven out from, or at least not encouraged to stay in, physics.

The second barrier is undoubtedly funding. It is very rare for an interdisciplinary collaboration to be excellent in all the disciplines involved. The underpinning nature of physics often means that its application in other areas involves building upon advances made, i.e. it is developmental rather than leading-edge. Currently, while recognising the problem, the research councils do not have a satisfactory means of sorting it out and, all too often, in a very competitive environment, peer review tends to downgrade interdisciplinary work in comparison with physics work at the leading edge. Interdisciplinarity is hindered when applications pass through two or more separate funding council review systems, and are therefore subject to ‘double jeopardy'. The way out of this longstanding problem would appear to be a change in the peer review system and, in particular, a need to fund good science, interdisciplinary or not, without an artificial split between disciplines being introduced at the review stage.

Finally, there is an issue of whether interdisciplinary research is identified as physics and is taking place in a physics department. While, in one sense, these are arbitrary questions, they are important both for the funding stability of the subject and for the perception of the outside world. There are no obvious incentives for a university to site such activities within physics (as opposed to another department). Perhaps the only route that might be effective is for the RAE, or its successor, to give explicit credit for this type of work. In the end, it may be down to individual university administrations being persuaded of the virtue of such arrangements.

The European Commission does a good job in fostering interdisciplinary research albeit with an unwieldy bureaucracy and an unhelpful requirement for ever larger consortia. They specifically fund networks that comprise scientists and engineers from a broad range of backgrounds. In contrast, there are very few calls from EPSRC that require extensive cross-discipline collaboration, and these are typically focussed on two named disciplines, such as chemistry and chemical engineering or physics and the life sciences.

Even though physics departments have been very successful in obtaining research funding from the Framework Programmes, the problem of covering full overheads is now, more than ever, a serious cause for concern. This situation is similar to that with UK research charities, which also do not contribute overheads. But we understand that a prospective increase in funding council research funding will be used to provide partnership funding to contribute to the overhead costs of research funded by UK charities. It is not clear whether a similar matching will apply to European funding. If not, such funding could actually be a burden, especially for smaller departments with little flexibility.

12. Please describe the value of physics as an academic discipline to the UK (consider both skills/knowledge acquired at undergraduate level and research)? Please provide detailed examples here.

Undergraduate level

Perhaps the greatest contribution that university physics departments make to the UK's economy is the annual production of trained physicists. Physics graduates provide highly skilled people in many nationally important areas, including the information technology sector, financial analysis, engineering, environmental science, energy technology, intellectual property law and medical physics.

Physics trains numerate people who are experts at problem solving. The ability to produce detailed, analytic and numerical descriptions of both simple and complex systems is a skill that has a wide range of applications. This ability runs beyond mathematics; it embodies notions of how things work, why things work and predicting how they will work under different conditions. These abstract problem solving skills are also coupled with very real understanding of technologically useful systems such as materials, electronics and mechanics, so there are clear, direct benefits to engineering and industry.

As part of the Institute's 'Undergraduate Physics Inquiry' of 2001[19], a survey was undertaken of the views of employers of physicists. There was a high demand for good physics graduates, with some employers having difficulty recruiting. Physicists find employment in a wide range of sectors, often far from what would conventionally be attributed to physics.

The current MPhys and BSc degrees produce high-quality mathematically-competent graduates who are eagerly sought by employers, who 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); and
- an ability 'to argue on one's feet'.

Postgraduate level

Just under 10 years ago, the Institute commissioned a major study[20] into the career paths of physics postdoctoral research assistants (PDRAs), with the aim of identifying the main business sectors and occupations in which physicists who had undertaken one or two PDRAs were employed.

For the 1988-1993 cohort, the study showed that, after universities, the private sector was the second largest employer of PDRAs, where the manufacturing sector was the main user of skilled PDRAs. Further analysis showed that within this sector, PDRAs were mainly employed in 'high-tech, leading edge' sectors, such as medical, precision and optical instruments, electronics and semiconductor products and computer and office machinery. These are high value-added industrial sectors which the government is keen to promote in building a strong, healthy and competitive industrial base.

The other main private sector 'users' of physics PDRAs were business/financial and software/computing companies. The majority of PDRAs employed in these sectors worked in computing-related occupations. However, other occupations include: financial/business analysts; actuaries; and commercial managers.

The five most frequently cited skills/competencies gained from PDRA research experience were (in descending order):

- Subject specific knowledge
- Presentation and communication skills
- Technical research skills

[19] www.iop.org/activity/policy/Projects/Archive/page_6337.html
[20] www.iop.org/activity/policy/Publications/file_26615.pdf

- Individual initiative and self motivation
- Problem solving skills.

These skills are in even higher demand today. Anecdotally, we often hear that the financial sector is keen to employ theoretical physics PhDs in preference to most other disciplines, due to the highly-numerate, analytical and problem solving skills that are acquired during their training.

Research

There is no shortage of examples illustrating the significant contributions that have been made to the UK's economy by fundamental research in physics. In terms of innovation, physics is more likely to produce new paradigms, whilst engineers are more likely to perfect existing ones. A combination of the two approaches is clearly vital to wealth creation in any developed economy.

One aspect of physics is often the time taken between the essential breakthrough in the science and the application. It is not so long ago that the laser was dismissed as a physicist's toy and not many people thought that atomic clocks would lead to the ability to navigate to within a metre at any point on the Earth's surface. The following examples help to illustrate how fundamental research feeds technology, the vast majority of which is physics based:

<u>Fibre optics</u>: In 1870, the physicist John Tyndall demonstrated that light follows the curve of a stream of water pouring from a container. This simple principle led to the study and development of the application of fibre optics, which over the last 50 years have had many uses in communication, medical imaging, traffic management, television and CCTV. Today, researchers at Heriot-Watt University are using fibre-optic technology enabling optical measurements to be made in real engineering environments, providing shape, vibration, velocity and acoustic measurements for applications in industry and mechanical engineering research.

<u>Lasers</u>: In 1917, the physicist Albert Einstein developed the concept of 'stimulated emission', which later evolved into laser light. This important development led to further research and development by a wide range of physicists, and today lasers are used in many everyday applications. These applications include all modern communications, including everything from cable television to the internet. Researchers at the University of Surrey are manipulating quantum cascade lasers which could be used as monitors of pollution, chemical processes and for medical diagnosis, i.e. glucose monitoring for diabetics.

<u>LCD technology</u>: Research that made LCDs possible was undertaken by interdisciplinary teams in the UK, including physicists and organic chemists, based in government research laboratories, universities and industry. Highlights include the first stable room temperature liquid crystal material, and two independent device developments (the amorphous silicon thin-film transistor and the supertwist display) which allowed LCDs to make the transition from simple displays for watches and calculators into complex displays for mobile phones, computer monitors and TVs. They have resulted in substantial revenue to the UK through sales of materials and royalty income from device patents.

<u>Medical Resonance Imaging</u>: The ability of MRI scanners to produce images of the human body is due to a fundamental property of nuclei: that they respond to magnetic fields. Isidor Rabi first observed the phenomenon in the 1940s in work that won him a Nobel Prize for Physics. In the 1970s, Sir Peter Mansfield working at the

department of physics at University of Nottingham, carried out research to develop rapid imaging techniques, allowing different types of tissue to be distinguished, leading to detailed images of organs such as the brain and the ability to distinguish between healthy and cancerous tissue.

Energy technologies: Beyond the middle of this century, new sources of energy that have a low impact on the environment and produce relatively harmless waste will be needed. Physics will play a crucial role.

Nuclear power: The UK government recently gave the private sector the green light to build new nuclear power stations, but there are widespread concerns that the UK is facing a skills shortage in the nuclear sector. The UK's future supply of nuclear engineers is dependent on a healthy nuclear physics research community, which provides a large part of the nuclear training and education at undergraduate, masters and doctorate-level. In passing, we note that the STFC funding cuts have hit the nuclear physics community particularly hard in light of the uncertainty following the transfer of their funding from EPSRC to STFC. It seems ill advised that cuts should be made on the research groups that train the new staff who the UK will rely on to play an integral role in a new build programme.

Renewables: Physics and physicists are playing an active role in developing and evaluating new and renewable energy sources based upon technologies such as wind turbines (both onshore and offshore), tidal power, wave power, fuel cells and photovoltaic solar power. In particular, semiconducting polymers are moving out of the research laboratory and into the market-place as industry realises the commercial potential of photovoltaics.

Climate change modeling: Physicists play a vital role in underpinning climate change modeling, by applying their quantitative skills and abilities to translate physical knowledge into sophisticated computer models. These important models enable scientists to keep track and forecast changes in the climate throughout the world, which supports the development of strategic carbon abatement policies, such as the Kyoto Protocol.

Future technologies: Looking to the future, in 2007 the Institute published the first in a series of reports, co-sponsored by EPSRC, which will showcase world-class UK physics research that has the greatest potential for commercial exploitation. The first report covered condensed matter physics[21] and demonstrated that physicists are tackling some of the major current scientific challenges. For example, in healthcare, condensed matter physicists based at University College London are manipulating exterior magnetic fields to heat up magnetic nanoparticles to target and kill cancer cells. A simple system for detecting whether breast cancer has spread into lymph nodes is in the process of commercialisation.

Physicists are also working on minute semiconductor structures called quantum dots, which will lead to applications to beat financial fraud. Physicists at the University of Cambridge and Imperial College London, collaborating with industrial partners, have successfully demonstrated single-photon quantum cryptography, a process which seeks to distribute securely a digital key that can be used to scramble information communicated between parties. If the key is encoded upon a stream of single photons, then it is impossible for a hacker to tap into the stream without destroying its integrity in a detectable way.

[21] www.iop.org/activity/policy/Publications/file_24889.pdf

13. Please detail any other points that you feel it would be useful for the review Panel to consider.

a) Physics is unusual in its mix of experimental and theoretical strands. Around a quarter of academic physicists are theoreticians, many of them working in institutions or departments that are dedicated to theory. There are a number of issues related to this point. One important one is that theoreticians have a lot in common with some mathematicians; for example, much of string theory research is carried out in departments of mathematics. However, theoreticians are treated as physicists in such matters as doctoral training accounts which can lead to anomalous situations whereby mathematicians receive more students than theorists with equivalent grant income. Another issue is the degree to which the funding agencies encourage joint working between experiment and theory, particularly in the EPSRC context.

b) Currently, there are a number of regional collaborations, driven by the perceived success of the SUPA collaboration in Scotland. It is probably fair to say that there are a number of reasons that universities are enthusiastic about working together with partners. There is an element of seeking extra funding that would otherwise not be available and there is also, in some cases, a fear of possible closure. More positively, there are genuine opportunities for: sharing postgraduate teaching; sharing major facilities; improving the coherence of research, in some cases achieving critical mass; and sharing responsibility for outreach. It is worth noting that the collaborations have largely, if not exclusively, been between physics departments, which sit uneasily with the idea of encouraging physics of an interdisciplinary or more applied character. Perhaps future regional collaborations, which always have a strong funding council input, could be encouraged to spread the net a little wider.

c) There is an anomaly in the allocation of the QR funding which works to the detriment of physics. A department receives funding from the funding council depending on its RAE grade but the allocation is also subject specific in that the pot of money available depends on the number of departments rated at grade 4 and above. Because physics has relatively more grade 5 and 5* departments than other subjects, because the weaker ones have closed, the money given to physics departments is less than that given to most other science and engineering subjects. In other words, because physics is overall stronger, it is given less money. This is neither fair nor sensible.

d) Finally, a word on the recent STFC funding controversy. It is the Institute's view that there are strong lessons to be learned, principally in the context of improved communication between the council and its grant holders. It appears that STFC is aware of this fact and is already taking steps in the right direction. However, the controversy, which attracted a lot of media attention, has undoubtedly reflected badly on physics and possibly discouraged young people who might be thinking of taking up the subject. The report of the RCUK Review of UK Physics will also gain a lot of media coverage. It would go some way to redressing the earlier bad publicity if the final report could be positive about the current and future importance of the subject, and emphasise how much the nation needs physicists.

The Institute of Physics is a scientific membership organisation devoted to increasing the understanding and application of physics. It has an extensive worldwide membership and is a leading communicator of physics with all audiences from specialists through government to the general public. Its publishing company, IOP Publishing, is a world leader in scientific publishing and the electronic dissemination of physics

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