The Royal Academy of Engineering

Review of UK Physics

Response to the Research Councils UK Physics Review Panel

May 2008

The Royal Academy of Engineering welcomes the RCUK Review of Physics and is pleased to submit evidence to the review panel. This response has been compiled using contributions from appropriately knowledgeable Fellows of the Academy. The Academy is content for its input into this consultation to be made public and would be pleased to provide supplementary evidence if required.

1.0 Please provide a description of the origins of the Royal Academy of Engineering and an overview of its present day functions

1.1 The Royal Academy of Engineering was founded in 1976 as the Fellowship of Engineering. The inaugural meeting was hosted by Prince Philip, a prominent advocate of the new body and the current Senior Fellow. The Fellowship was established with the purpose of recognising the contribution of engineers to society and providing expertise and advice on engineering-related matters. In 1992 its success in promoting engineering excellence were recognised when it was granted a Royal Title and became The Royal Academy of Engineering.

1.2 The Academy's work programmes are driven by three strategic priorities[1], each of which provides a vital contribution to a strong and vibrant engineering sector and to the health and wealth of society. The strategic priorities are (i) enhancing national capabilities; (ii) recognising excellence and inspiring the next generation, and; (iii) leading debate. Current work programmes focus on education, research schemes, events and awards and policy and public affairs.

2.0 Please detail how the Royal Academy of Engineering supports physics academics in the UK. Describe the support the Royal Academy of Engineering gives to academics in achieving economic impact and wider user engagement.

2.1 The Academy does not directly fund or support physics academics. However physics and engineering are intrinsically related, and a significant minority of the Fellowship and academics involved in Academy research schemes have physics backgrounds. For example, 10% of Academy Fellows are also members of the Institute of Physics, and at least 16% of the Academy's post-doctoral Research Fellows have a physics background (i.e. undergraduate and/or postgraduate degree in physics).

[1] http://www.raeng.org.uk/about/default.htm

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

3.1 The Academy honours the UK's most distinguished engineers from all branches of engineering. There are 1383 Fellows. The following information indicates the composition of the Fellowship:

- Disciplines:

Discipline category	% Fellows
Mechanical[2]	27
Civil and structural	23
Electronics, electrical, IT and informatics	28
Process and chemical[3]	22

- Professions:

Profession category	% Fellows
Academic	25
Industrial	18
Consultant	17
Government/not-for-profit	3
Retired	37

- The age range is 38-98 years, with the average at 70 years[4]
- The gender profile is 98% male and 2% female[5]
- Of those in academia, around 96% have the title of 'Professor' or higher

4.0 Please describe the value of physics as an academic discipline to the UK (consider both skills/knowledge acquired at undergraduate level and research).

4.1 Physics teaches a useful scientific outlook and respect for data. These skills are important to the UK and are a logical progression from numeracy and literacy. The UK has a long-standing reputation for pursuing knowledge, and physics is essential to continuing this trend.

[2] Includes aeronautical, naval and manufacturing
[3] Includes petrochemical and fuels
[4] Data has been extrapolated to be accurate on 7 July 2008 (the Academy's AGM)
[5] Estimated on 13 May 2008

4.2 Physics teaches many skills, such as identifying and solving problems, experimental design, interpretation of data, team work and leadership, research methods and management of large-scale and complex programmes. These transferable skills make physicists highly employable in many sectors. Physics is an enabling and underpinning discipline for engineering and other science disciplines.

4.3 Physics is of great economic value to the UK, particularly if those elements of engineering activity which are closely related to physics are included. The Institute of Physics (IOP) claims that turnover of physics-based industry in the UK in 2005 was £180 billion, or 9% of the total economy's turnover[6]. A demonstrative case study is Sharp Laboratories of Europe, which has an annual turnover of £15 million. Around 43% of the staff are physicists. The company is a typical component of the knowledge economy, with high-value jobs and a large percentage of turnover spent locally through salaries. However company growth is constrained by the lack of good physicists.

4.4 From providing the development of financial models in the city, to allowing the safe operation of nuclear reactors, physicists are engaged at all levels in ensuring the economic health of the country.

4.5 Physics is essential for an adequate understanding of many nationally (and internationally) important issues including energy, pollution, defence technology and transport. It will continue to be the source of important future developments in these and other fields.

5.0 Comment on the importance of physics in underpinning allied disciplines. Comment on the willingness of the discipline to work in collaboration with other disciplines (interdisciplinarity). Please provide examples.

5.1 Physics provides the underpinning knowledge for most engineering disciplines. Physics also underpins countless scientific, technological and medical developments. The development of rigorous analysis, the proper testing of new theories and the attitude towards integrity of knowledge are aspects of physics that are vital to many fields. Therefore physics ensures the development of many related subjects, as well as providing the underpinning science of many industrial activities.

5.2 Some significant examples include:

- Medical advances, such as imaging technology (X-rays, MRI) and instrumentation for blood gas and flow measurements
- IT and electronics, which are increasingly driven by inorganic semiconductor and liquid crystal technology

[6] http://www.iop.org/activity/business/Publications/Physics_and_the_Economy/file_26914.pdf

- The internet, grid computing and communications, which have been further enhanced by optical fibre technologies that revolutionised long-distance communications
- Light emitting diodes, which have applications ranging from lighting to medical devices, clothing and signs.

5.3 The extent of interdisciplinary working is variable. However, physicists are generally willing to collaborate with researchers from other disciplines. Although there is a general willingness amongst physicists to work in collaboration, anecdotally it is not as widespread as desired. There are various reasons for this, including the reticence of universities to teach students about the practical applications of their work. Physics departments are usually reasonably interdisciplinary by nature; however physics is one of the basic sciences, and there is often a need to maintain a focus on fundamental research.

5.4 Examples of interdisciplinarity include:

- Research into challenges such as climate change and energy, where physicists and engineers are working together to produce solutions
- Joint research projects between academia and industry, where physics research can be applied to practical engineering problems
- Large-scale physics experiments and sharing of facilities. For example. the STFC physics facilities are open to and are regularly used by non-physicists.

5.5 As physics is an underpinning science, physicists often move into other disciplines. Where their physics skills and knowledge are exploited is an example of interdisciplinarity and collaboration. Physicists commonly move into engineering, medical technology and materials science roles, among others. These types of collaboration have led to many advances in techniques and understanding; their importance should not be underestimated.

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

6.1 We believe the UK has a strong research base, with particular strengths in theoretical physics; particle physics and astronomy.

6.2 We believe that UK physics has many weaknesses. These are detailed further below, and include:

- Provision of high-quality teaching (Section 6.3)
- Public perceptions (Section 6.4)
- Recruitment and retention (Section 6.5)
- Funding (Section 6.6)

6.3 Provision of high-quality teaching

6.3.1 We believe that the teaching of physics in the UK has serious weaknesses, particularly at pre-university levels. The quality of teaching could be improved by ensuring that teachers have physics backgrounds or appropriate training and knowledge of the subject. The relationship between provision of qualified physics teachers and the uptake of physics have been well studied and a 20 year decline[7] in the study of physics can be partly attributed to reduced quality of teaching. State schools find it more problematic to employ and retain good physics teachers. A 2005 report found that 10% of state schools no longer offered physics A-level[8], and the situation has not changed significantly.

6.3.2 Oxfordshire illustrates the problem: despite being a scientific hub, there are 156 biology teachers, 98 chemistry teachers and only 75 physics teachers in the county's schools[9].

6.3.3 We are very concerned about the poor provision of good quality physics teaching in schools. A high proportion of engineers require physics A-level, so a reduced number of physics students results in a reduced number of potential engineers. We suggest that the Review Panel examine ways to increase the quality of physics teaching in schools.

6.4 Recruitment and retention

6.4.1 Recruitment is a long-term problem for the UK. For those who do pursue careers in physics, the financial rewards can be poor in relation to other professions where a similar level of intellect and ability is required.

6.4.2 There is a perception that physicists should be motivated by a 'love of the subject' rather than financial gain[10]. However we believe that this attitude can compromise the retention of the best physicists in science and engineering, and therefore the quality of UK physics. This issue also affects the availability of good physics teachers; people with good

[7] http://www.hm-treasury.gov.uk/media/5/E/sainsbury_review051007.pdf
[8] http://www.buckingham.ac.uk/education/research/ceer/pdfs/physicsprint.pdf
[9] Private communication. Facts based on 34 county schools
[10] As recently demonstrated by John Womersley (Director of Science Programmes, STFC) on BBC's Newsnight programme; http://news.bbc.co.uk/1/hi/sci/tech/7338666.stm

physics training can often get better paid employment than teaching. For example, physicists and engineers are highly prized and well-paid in the financial sector.

6.4.3 Aside from improving teaching and public perceptions (which are detailed separately), we suggest the following measures to improve recruitment.

6.4.4 There should be better pay and bursary structures to attract and retain young physicists, and possibly financial incentives to encourage potential physics students to study the subject. Better financial incentives should also be provided for physics graduates, or those in similar disciplines, to qualify and work as physics teachers.

6.4.5 There should be stronger mechanisms to enable non-physicists, or those who have moved out of physics, to enter or re-enter the field. This should include vocational training and training for technicians. These are useful ways to recruit talented, skilled individuals who are less inclined towards academia.

6.4.6 Universities should ensure that students are suitably trained for careers in industry as well as research. Universities should invest greater effort in demonstrating to how a physics degree can provide transferable skills for the majority of students who will not follow careers in academia

6.4.7 Universities should make it easier for ambitious young researchers to establish themselves in academia. This can be problematic where relatively ageing faculties exist, and requires that universities be helped financially with early-retirement programmes. The funding structure should also recognise that many young researchers today will remain on fixed term contracts for longer than has traditionally been customary.

6.4.8 In addition to these suggested measures, the UK must remain competitive in attracting international PhD students (and not losing UK students abroad).

6.5 Public perceptions

6.5.1 In the UK it can be challenging to engage the public with science and engineering. Public engagement is vital to raise awareness of the value of science and engineering and their impact on contemporary society. The importance and relevance of physics to peoples' lives needs to be communicated more effectively. The subject needs champions and role models who can convey the excitement and importance of physics to a wider audience.

6.5.2 The physics community has a relatively low profile in space research and programmes. Space is a fascinating subject to young people, and the lack of UK representation in relevant programmes is a missed opportunity to inspire the public. Conversely, there is also little communication to the public about the very real benefits of other physics research (e.g. in climate change or medical research).

6.5.3 Physics is often perceived to be extremely difficult, which discourages potential students and makes the subject seem less accessible to the public. Physics addresses some of the most fundamental philosophical questions, but the public perception of intellectual elitism needlessly distances the public from physics. This perception is sometimes enhanced by the views of scientists themselves.

6.5.4 We strongly believe that the scientific community should continue with endeavours to inform the public about the real benefits of science and engineering. In addition, a key message should be that physics is a challenging but also rewarding study and career option that is accessible to a diverse group of people. (Increasing the entry routes into physics careers will enhance this message; please refer to section 6.4.5)

6.6 Future priorities

6.6.1 Physics underpins other disciplines such as engineering, which is essential for solving many of the challenges faced by the global population today. Amongst the most important are energy security and climate change. In the UK, physics will also increasingly play an important role in the growth of the nuclear industry. There must be strategies to ensure that sufficient skilled physicists and engineers will be available to enable the revitalisation of nuclear power as planned by government.

7.0 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?

7.1 A significant weakness of UK physics results from the government's attitude to funding.

7.2 Experimental physics relies heavily on the ability of UK physicists to participate in international programmes. Inconsistency in commitment to these programmes makes it difficult for physicists to access and participate fully in leading research. In addition, it damages the UK's reputation as a reliable international partner. There has been international concern resulting from the handling of attempts to reduce funding for the Gemini astronomical project. British researchers are currently developing the first complex mirror segments for the European Southern Observatory (ESO) 42m Extra Large Telescope, yet there is a possibility that UK's reputation for inconsistent support could jeopardise any full production follow-up.

7.3 We believe that government should recognise the need for consistent, long term support of agreed international programmes; national research programmes should be treated similarly. In principle there should be commitment to funding projects over the full timescale required. Major breakthroughs have been enabled by significant support of basic science over a long period, enabling key innovations to be made at the right time. This often requires faith, i.e. supporting research even though the potential benefits may be unknown or unquantified.

7.4 Funding for large facilities must be considered within an international dimension. Abrupt cancellations of agreed international commitments have not occurred at pre-agreed point, thus tarnishing the UK's reliability and reputation. We recommend that review points should be clearly defined within existing contracts. There should be better management of contracts, and the UK should potentially withhold on new initiatives until older ones are brought to an agreed end.

7.5 Funding for smaller facilities is generally sufficient. There are well-proven processes for getting equipment and initiatives such as the Science Research Investment Fund[11] have been successful.

7.6 Particle physics and astronomy research were well supported with the dual income stream from the Particle Physics and Astronomy Research Council (PPARC) and Engineering and Physical Sciences Research Council (EPSRC). When PPARC was merged with the Council for the Central Laboratory of the Research Councils (CCLRC) to form the Science and Technology Facilities Council (STFC) in 2007, funding streams became more complicated, but in principle the merger should improve interdisciplinarity.

7.7 The UK's funding structure and budget cycles can be precarious for early career physicists trying to enter research. In early career stages it could be more beneficial to support people rather than proposals.

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

8.1 The UK is well endowed with major facilities that it either owns or has access to through international subscriptions. However the funds to run and access these facilities are limited, resulting in a sub-optimum use of resources. When future large facilities are agreed it is essential that realistic long-term plans to cover operational costs are established.

8.2 Scientific and medical research is constantly delving deeper into fundamental underlying processes. This has led to an increasing need to understand physics theory, methods and analytical techniques. As a

---

[11] http://www.hefce.ac.uk/Research/SRIF/

result, many large-scale physics facilities are regularly used by non-physicists. This accessibility helps to sustain physics research facilities.

8.3 Consideration should be given to secure methods of limiting the impact of exchange rate movements on subscriptions to international facilities.

9.0 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?

9.1 There are some weaknesses in teaching at universities. Physics is an extremely broad subject and students' interests can often become very specialised, to the detriment of more fundamental knowledge. In addition, many undergraduate and postgraduate courses train students better for careers in physics research than in industry, which is a problem for some employers and for encouraging interdisciplinarity.

9.2 We believe it is appropriate that physics degrees should continue to be reviewed and accredited by the Institute of Physics. Accredited degrees should incorporate a strong practical or applied element.

9.3 Please refer to our previous comments on provision of high-quality teaching (section 6.3) and recruitment and retention (section 6.4).

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

10.1 The current problems facing the STFC highlight the tension between pure science conducted primarily for the pursuit of knowledge and research for which economic impact can be more directly measured. The Diamond Light Source and other such facilities can be more readily justified by strategic economic arguments than particle physics and astronomy,

10.2 Government and government agencies need a clear, consistent and maintainable strategy for funding and maintaining UK physics. This strategy should include a holistic planning process to ensure that the demand for research grants and facilities can be reasonably fulfilled.

10.3 Physics and other scientific research underpin engineering. However this relationship is reciprocal. Across the sciences, research is often facilitated by engineering, e.g. increases in computing speed and power that have made ever more complex data processing, calculations and predictions possible (climate science and genomics in particular). High energy physics and astronomy also rely on engineers to conceive, design, implement and operate the large scale facilities required. A huge proportion of scientific research is completely dependent on technologies produced, maintained and improved by engineers. Engineering and physics are mutually interdependent.

Submitted by:
Phillip Greenish CBE
Chief Executive
The Royal Academy of Engineering
23 May 2008

Prepared by:
Xameerah Malik
Policy Advisor
The Royal Academy of Engineering