Physics Education

Physics and engineering

The project

The A level examination in physical science does not include a practical examination. However, every candidate has to undertake a practical project, which is intended to occupy about 10% of the total course time. By being assigned a problem which will demand his attention for a proportion of his time, over a period of (perhaps) two or three months, by having to plan his work, and by having to develop an experimental technique and overcome difficulties, each student should come to appreciate something of the flavour of scientific research. Although most problems are not original in any absolute sense (although some are) the essential point is that neither the student (nor, possibly, his teacher) knows the answer. Naturally, students usually choose projects according to their own interests. The titles of some projects from the past year or so, with a physics or engineering content are: 'A CRO Display of Water Surface Waves'; 'An Ultrasonic Range-Finder'; 'The Frequency Response of Microphones'; 'The Physics of Wind Instruments'; 'An Electromagnetic Gun'; 'Measurement of the Velocities of Beta Particles'; 'Communication by Modulated Light'.

Each student writes a short report on his project, and the teacher who supervises him assesses his work according to a scheme prepared by the examiners. In this scheme, regard is paid to the various qualities tested by project work, and care is taken that projects of different kinds are assessed in such a way that the particular characteristics of each receive due credit. In standardising the project marks from different schools, the examiners and project moderators (who visit each school from time to time) try to allow for such factors as the general facilities of the school, the laboratory and technical assistance which is available, and its craft tradition, if any. The project counts for 50 marks out of a total of 350, in the A level examination.

The special paper

The special paper in Nuffield physical science is set on the whole course—that is, on both the basic course and the options. Although the syllabus is thus essentially the same as for the A level papers, a higher standard of knowledge and understanding is naturally expected.

Further information

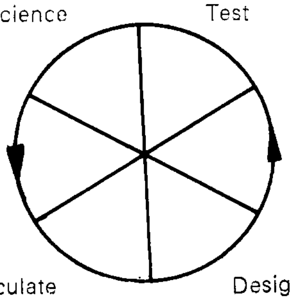
Further information about the course can be had by writing to the Organizer, Dr J E Spice, 12 Kingsgate Street, Winchester.

Physics and Engineering

G Jackson
Department of Mechanical Engineering
Brunel University

In recent years several new GCE A level engineering syllabuses have attempted to unite physics and technical studies. The following notes describe their purpose at greater length than can be indicated by the one or two words of their titles. The two key words for the disciplines in question, the two cultures of 'knowing' and 'doing', are too pretentious and too vague ever to appear in titles; some of their obvious sub-divisions are seldom seen. The relevant sub-divisions are science, mathematics and calculation on the one hand, and designing, making and testing on the other. The first group corresponds to analysing the facts, reasoning out the consequences and being numerate about the deductions. The second group, until you come face to face with the need to follow it through, is self explanatory. Each of these six sub-divisions fragments in turn into a multiplicity of specialisms. If these are not immediately forthcoming in the reader's recollection, a few minutes reflection should fill the gap.

Over the years dissection and the naming of the sub-divisions of knowledge has gone so far that specialized pursuit of the part has produced a resurgence towards the whole, the beginnings of a return towards a matured 'natural philosophy'. Integrated courses and inter-disciplinary studies are attracting more and more attention and, alas, more and more names. Science, mathematics and calculation have, since perhaps the appointment of Maxwell to Cambridge, formed an integrated course under the banner of 'the science stream'. In its professional use, the repeated application of science, mathematics and calculation, in that sequence, is a procedure for the progressive refining of a scientific theory. If an occasional injection of newly measured data can be obtained by standard methods and if off-the-shelf instrumentation reduces data collection to a routine task, the theorizer can separate himself from the details of the design and construction of apparatus, perhaps even from its use. In like manner designing, making and testing form the backbone of technical studies, another integrated course, and the three steps in sequence are used professionally for the progressive improvement of an existing design. It is not essential for the practitioner of craft skills soundly grounded in traditional techniques nor for the technologist depending on a more recent scientific inheritance to be closely involved in scientific theory. When however a scientific theory is propounded which is new or when a novel design is proposed, or when a significant extension of understanding or of technique is envisaged, knowing and doing become inseparable.



If the six steps are seen as sectors of a circle, iteration around this circle provides, for the benefit of people with ideas, a method of examining the worth of an idea and testing its probable validity against a background of existing knowledge and method. Professional investigation of a new idea ends when, within an acceptable time and at an acceptable cost, tested performance accords well enough with calculated prediction. Every investigation starts in the science sector of the circle in order to identify and calculate whatever is calculable, to pinpoint the assumptions and uncertainties of the calculable and quickly to narrow the region where unguided intuition can lead to error and loss. The risks are to be calculated risks. Good doing requires meticulous intellectual effort, however humble the act, for there is a surgical finality about the decision "Yes, saw it off there. That will do the job". Conviction, experience and faith come together in a complete design. Technology being what it is and because the knower is rarely the sole doer, design culminates in a full, unambiguous and understandable description; technical drawing is but one of the descriptive methods.

There is a German proverb, Wissen ist nicht Können. There is room for another, Können ist nicht Wissen. The short-fall between achievement and expectation calls for intellectual honesty and logical analysis to extract, display and make good the revealed defects in initial understanding. If it does not force acceptance of the fact of failure, it calls for a second or a third time round the circle, and the attendant old-fashioned virtues of a Samuel Smiles or a Robert Bruce.

As pictured, this is a feed-back loop with neither input nor output. It appears to survive by devouring its own young. The input is of course the novel idea, and this test-card is no aid to inspiration or creativity. Corresponding to the input idea being either a scientific hypothesis or a hardware invention, the output or spin-off from the circle is either a proven theory or it is an artefact, something that works. If the former, a contribution has been made to scientific research; if the latter, a contribution to engineering.

A survey (Porter 1967) of the efforts made by educationalists and others to resist the fragmentation of teaching in this field underlines that for many pupils a subject like mathematics remains obscure, often a hurdle to be negotiated on the way to a qualification, but if the pupil can see that mathematics is both a tool and a language for practical men he will be able to accept and to understand much more readily. The Porter survey, written at the time when the GCE boards were recognising that their conventional syllabuses did not make such a link, is essential reading for an understanding of the background and origins of inter-disciplinary A level courses. Some boards (eg Oxford) were strongly influenced by the experience of forward-thinking technical teachers, many of whom were preparing pupils for craft, technical or drawing examinations at O or A level, and their first syllabuses built scientific analysis upon a foundation of design studies and workshop subjects in mechanical and electrical engineering. Other boards (eg JMB), more conscious of objections from professional scientists and engineers that analysis had become too remote from application, moved towards an applications-oriented recasting of their scientific courses. Syllabuses of both kinds have been examined over the past four or five years. All have two major components. The first is problem-solving in its entirety, achieved by the project method. Students spend a good proportion of their time on open-ended investigations, starting with a design problem or a construction problem and aiming at a full-circle exploration. The second component of the syllabus is a deeper, more traditional academic study of one or more of the six sectors.

Details of three current 'engineering' syllabuses are given in the table. As originally published, they all tended to contain too great a total volume of work and

Examining Board	Title	First examined	Syllabus		Examinations		Marks		Notes
			Course work	Other	Course work	Other	Course work	Other	
Oxford Local Examinations The Delegacy of Local Examinations Summertown Oxford	Engineering	1966	Several projects occupying about 150 hours total over 2 years. List of project suggestions available.	1 Study of mechanical and electrical design problems. 2 Materials, metrology, mechanics, electronics, electrical engineering, manipulation of materials.	Oral examination and assessment by examiner	1 One paper of no fixed duration on Design. Candidates discuss solution with visiting examiner during assessment of course work. 2 One 3-hour paper on Principles of Engineering	$33\frac{1}{3}$%	$33\frac{1}{3}$% $33\frac{1}{3}$%	Recommended to be taken in addition to Mathematics and Physics, but these are not mandatory.
Associated Examining Board Wellington House Station Road Aldershot Hants	Engineering Science	1969	Laboratory experiments plus a project. List of project suggestions available, outline must be submitted for approval in advance. Complete records of laboratory and course work must be kept.	Science of materials; mechanics, machines and tribology; thermodynamics and mechanics of fluids; electrical and electronic principles.	Assessed by teacher. Each centre is visited by the Moderator or his representative and course work must be available for inspection.	Two 3-hour papers	16%	84%	Alternative to Physics
Joint Matriculation Board Manchester M15 6EU	Engineering Science	1969	About 110 hrs total over 2 years, including about 50 hours on a major project, not necessarily experimental but necessarily including a design element. Project outline to be submitted in advance for Board approval on first occasion.	Mechanics, materials science, physical transport phenomena, waves and vibrations, basic systems analysis, field phenomena, electron physics and devices, thermodynamics and energy conversion.	Initial assessment by teacher. Interview by examiner.	Two 3-hour papers.	Pass essential. 20%	80%	Alternative to Physics

either too ambitious a span or too detailed a scrutiny of too narrow an area. Differences are becoming less marked as each moves towards a wider view and a better integration.

All three boards would like to widen their catchment. All have guidance material for newcomers. The JMB has text books for students and a guidance booklet of some fifty pages. The Oxford Board, still pioneering, has another variation on a closely related theme. Its Design syllabus boldly grasps feelers stretching out towards engineering from art and architecture. The Cambridge Local Examinations Syndicate has an A level paper entitled Elements of Engineering Design, directed more specifically towards the use of engineering materials. This board also offers to candidates for its physics paper the opportunity to improve performance by one grade as a result of doing well with a project and an oral examination. A distinctive feature of this particular variant is that its project work is additional to a conventional practical examination in physics. The Engineering and the Engineering Science papers do not include practical examinations in the conventional sense.

Northern Ireland has an Engineering Science paper. Rumour has it that London will have one tomorrow. Some time ago London entered the field by including a design project in A level engineering drawing.

This is not an exhaustive list of all the relevant papers. Including every paper which might be mentioned, it is doubtful if the proportion of science-stream students exposed to them amounts to more than one per cent of the total. Although they are welcome in university departments of physics and engineering and in some medical, dental and veterinary science schools, this relatively small number of students provides neither the opportunity nor the impetus to follow through with a revised first year university course. A group of students with good grades would offer this opportunity. Of necessity they would lack some of the detailed scientific knowledge we have come to expect but they would have acquired a measure of confidence in their own ability to extend their knowledge and to make use of what they learn.

The advance and penetration of the new papers depends on the aptitudes and adaptability of teachers. Since the publication of Mr Porter's paper, the Schools Council has through Project Technology offered help and guidance. Selected articles from Project Technology's bulletins published since 1968 have recently been reprinted (School Technology). Regarding the teaching of design, if it is to be related to real life industrial applications informed teaching is scarcely possible without first-hand industrial experience. Methods of linking school and industry are outlined as part of a recent publication (Support for school science and technology) surveying the form, function and finance of school science, mathematics and technology centres in the United Kingdom, including physics centres set up in association with the Institute of Physics. Teachers in schools, colleges, polytechnics and universities who are anxious to participate in the current developments would do well to locate and become associated with the activities of the nearest centre. Although much can be gained by collaboration within the educational system and with local industry, second-hand knowledge is a poor substitute for first-hand participation. A prerequisite for giving reality to these new syllabuses is that the teachers should have had experience of doing things in earnest.

Acknowledgments

The author would like to thank J F Gamblin, R W Hughes and J Clark for checking the table and for providing their general view of the subject. It should be noted, however, that the views expressed in the article are those of the author.

References

Porter D I R 1967 *A school approach to technology* (HMSO: Schools Council Curriculum Bulletin No 2)

School Technology 1971 Vol. 1 and Vol. 2 (London: English Universities Press)

Support for school science and technology 1971 (London: Evans/Methuen Educational)