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Content Evaluation of Traditional Core Physics Courses in Engineering Curricula*

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Core physics courses are prescribed in engineering curricula by professional and accrediting bodies. However, factors such as curriculum crowding and time constraints frequently bring into question the content and the extent of coverage of these courses. A survey was undertaken to assess the attitudes of engineering faculty to physics, mathematics and chemistry courses. The results for physics confirm that, while many of the classical topics in physics are perceived as relevant in engineering curricula by all faculty, topics in modern physics are not. Furthermore, variations in attitudes towards modern physics exist on a departmental and regional basis. This paper presents the results of the physics survey, with an analysis of attitudes towards physics in general in engineering curricula and to individual topics in particular, and tries to suggest reasons for the variations in departmental and regional attitudes.

INTRODUCTION

SOME 50 YEARS ago, a paradigm shift in engineering education occurred. This shift came about from the realisation that, in order to participate more effectively in the rapidly developing post-war technologies, engineers needed a firm foundation in mathematics and the physical sciences. Thus, practice-oriented courses such as machine shop and mechanical drawing were dropped from the engineering curriculum in favour of mathematics and basic science courses [1]. Subsequently, basic sciences, in particular physics, became an indispensable component of the engineering curriculum. An adequate background in science and mathematics, since then, has been considered 'a reason that engineers have been able to sustain productive careers' [2]. The complementary role of physics in innovative high technologies has ensured it a permanent place in the engineering curriculum [3, 4, 5].

From the mid-1980s, physics education research has been providing invaluable guidance to designers of freshman physics courses [6]. While designing such courses for engineering students, it is desirable to know the expectations of engineering faculty. For this purpose, we designed a survey (available for download from http://ltac.emu.edu.tr/B_questionaireCMP1ext.doc) to assess the attitudes of engineering faculty to mathematics and physical sciences. In this paper we report our findings from the physics part of the survey, which sought to find answers, amongst others, to the following questions:

1. Which topics should be covered, and to what extent, by introductory physics service courses?
2. Which of the skills offered in physics do engineering faculty consider as being most relevant to engineers?
3. Are there any differences in the attitudes towards physics of engineering faculty from different departments?
4. Are there any differences in the attitudes towards physics of engineering faculty from different countries?

In order to form a common base for European engineering education, the SOCRATES Thematic Network E4 (Enhancing Engineering Education in Europe) proposed some guidelines for engineering core profiles. According to this proposal [7], as far as physics is concerned all graduate engineers should be able to:

a) Use the relevant laws of kinematics and dynamics to solve problems of rotational and lateral movement.
b) Explain harmonic oscillations, damped oscillations, and forced oscillations and treat such oscillations mathematically.
c) Describe waves mathematically and explain the concept of wave lore.
d) Explain the first and second law of thermodynamics and solve problems applying these laws.
e) Explain the principles of electric and magnetic fields and apply the basic laws of electric circuits.
f) Explain the basic principles of quantum theory

A further purpose of this paper is to assess the extent to which present attitudes of engineering faculty are in conformity with these guidelines.

THE SURVEY

The physics part of the survey consisted of four sets of items: one set relating to general skills and

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Table 1. List of the physics items in the survey

Item	Description
	Set 1: Generic Skills and Knowledge
1	Problem-solving
2	Exposure to instrumentation and laboratory
3	Teamwork in experiments and problem-solving
4	Basic principles of classical physics (mechanics, thermodynamics, electricity, magnetism, optics, waves)
5	Basic principles of modern physics (quantum physics, relativity, solid-state physics)
	Set 2: Physics I Topics
6	Measurement, units, estimating
7	Kinematics in one dimension
8	Kinematics in two dimension, vectors
9	Dynamics, Newton's laws of motion
10	Applications of Newton's laws
11	Gravitation
12	Work and energy
13	Conservation of energy
14	Linear momentum and collisions
15	Rotational motion about a fixed axis
16	Vector product and torque
17	Angular momentum
18	Static equilibrium
19	Simple harmonic motion
20	Fluid mechanics, pressure, Bernoulli's equation
21	Wave motion
22	Sound waves
	Set 3: Physics II Topics
23	Kinetic theory of gases
24	Heat and the first law of thermodynamics
25	Second law of thermodynamics
26	Electric charge and electric field
27	Gauss's law
28	Electric potential
29	Magnetism
30	Sources of magnetic field
31	Electromagnetic induction and Faraday's law
32	Geometrical optics
33	Interference, diffraction, polarisation
34	Nuclear physics
35	Cosmology
	Set 4: Physics III Topics
36	Special relativity with Lorentz transformations
37	Blackbody radiation, photoelectric effect, Compton scattering, x-ray diffraction
38	Atomic structure, Rutherford and Bohr models of the atom
39	Matter waves; de Broglie's hypothesis, Davisson-Germer experiment
40	Heisenberg's uncertainty principle, wave-particle duality
41	Introduction to quantum mechanics
42	Simple applications of the Schrödinger's equation
43	Simple harmonic oscillator, tunnelling, hydrogen atom
44	Selected topics from solid state physics

knowledge, and the other three sets corresponding to specific subject topics in the traditional Physics I, II and III courses, although it must be stressed that individual syllabi may differ among universities. The first three items in the first set were on generic skills, while the remaining two were on general knowledge about Classical and Modern Physics. The items of the other three sets were topics usually covered in separate chapters in traditional University Physics textbooks [8, 9]. Table 1 lists all the physics items contained in the survey.

In set 1, the participants were asked to rate the importance of each of the generic skills/knowledge item in relation to their specific engineering program. In the remaining sets, the participants were asked to rate the relevance of each topic to their own engineering discipline. Participants rated the items on a 5-point Lickert scale: 1 = unnecessary, 2 = not relevant, 3 = optional, 4 = relevant, 5 = essential.

Table 2. Distribution of respondents by department and region

	DEPT				
REGION	CE	EC	EE	ME	ALL
AMER	37	35	18	42	132
EURO	7	13	12	9	41
NCTR	22	13	22	26	83
UK	5	3	4	13	25
OTHER	14	5	6	13	38
ALL	85	69	62	103	319

The survey was conducted online and was managed automatically by an in-house-developed Survey Management System (SMS), designed to be capable of handling any suitably formatted electronic questionnaire. The survey questionnaire was sent out as an e-mail attachment to 6985 addresses taken from the websites of 101 universities from 27 countries. Over a period of three months, 319 replies were received. The distribution of respondents by department and geographical region is presented in Table 2.

The questionnaires were returned as e-mail attachments. Each returned e-mail and questionnaire was received by the SMS, which processed and recorded the respondents' details and responses to the items in a survey database. The complete data processed by the SMS was then organised and analysed. The respondents were categorised by their department affiliation and by institution country. Some categories, however, had only a few participants, and these small groups were either combined or added to larger ones to create statistically meaningful categories. The final groupings are based on generic department affiliation (labelled as DEPT) and on the geographical locations (REGION) of the respondents' institutions. The groupings for the department (DEPT) category are:

CE = Civil Engineering, Civil and Environmental Engineering, and other related departments.
EC = Electrical and Computer Engineering, and Computer Engineering departments.
EE = Electrical and Electronics Engineering and other related departments.
ME = Mechanical Engineering, Industrial Engineering, Materials Science and other related departments.

The groupings for the geographical location (REGION) category are:

AMER = Canada and United States of America.
EURO = Belgium, Finland, Germany, Greece,

Iceland, Ireland, Italy, Malta, Netherlands, Poland and Sweden.

NCTR = North Cyprus and Turkey.

UK = United Kingdom.

OTHER = Australia, Brazil, Egypt, Hong Kong, India, Israel, Japan, Lebanon, Malaysia, and United Arab Emirates.

The UK has been grouped by itself because the number of respondents is sufficiently large for statistical treatment, and its higher educational system is fairly distinct from the rest of Europe. The group NCTR, comprising North Cyprus and Turkey, is joined for three main reasons: first, the respondents are from universities based on the North American model; second, the strong political and cultural ties between the two countries and the consequent similarity of their educational systems justify a combined treatment; and third, the total number of respondents in this category is adequate for statistical analysis.

RESULTS AND DISCUSSION

In order to simplify the interpretation of the responses, the five points were converted to three distinct 'attitude' ratings and coded as follows:

Rel = Relevant, corresponding to the combined Essential and Relevant responses (points 5 and 4 on the Lickert scale).

Opt = Optional, corresponding to the Optional response (point 3).

Non = Not relevant, corresponding to the combined Not relevant and Unnecessary responses (points 2 and 1).

In the rest of the paper, the use of the terms 'relevant', 'optional' and 'not relevant' will refer to these definitions.

The percentages of ratings given as relevant to all items in each set are plotted for different departments in Fig. 1, and for different geographical regions in Fig. 2.

From Figs. 1 and 2, it is overwhelmingly clear that the majority of respondents, whether grouped by department or region, rated the general knowledge and skills items in Set 1 as relevant. In the case of the topic items sets, there is a clear decreasing trend in the relevant rating from Physics I to Physics III. Physics I is the only set receiving a higher than 50% relevant rating from each group. However, differences exist amongst departments and regions in their rating percentages of Physics II and III.

With regard to the departmental attitudes summarised in Fig. 1, CE faculty were the only group rating Physics II with a less than 50% relevant response, while EE faculty were the only group rating Physics III with a more than 50% relevant response.

Regional attitudes, as summarised in Fig. 2, show that North American faculty consistently

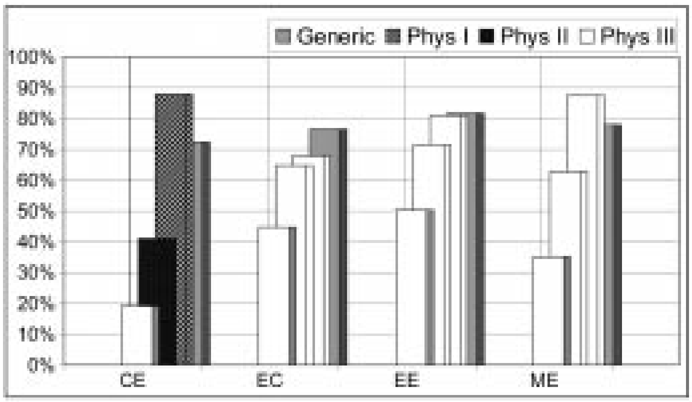

Fig. 1. % Relevant ratings given to each item set by departments.

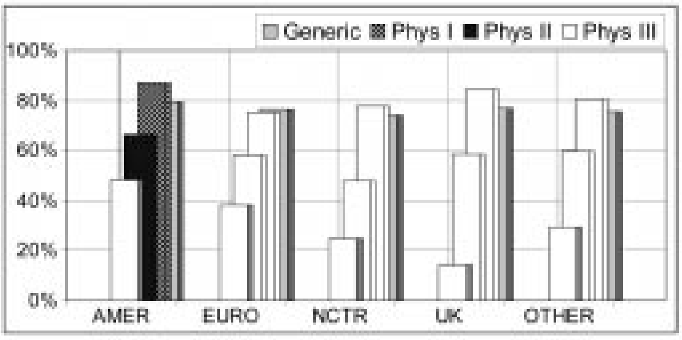

Fig. 2. % Relevant ratings given to each item set by regions.

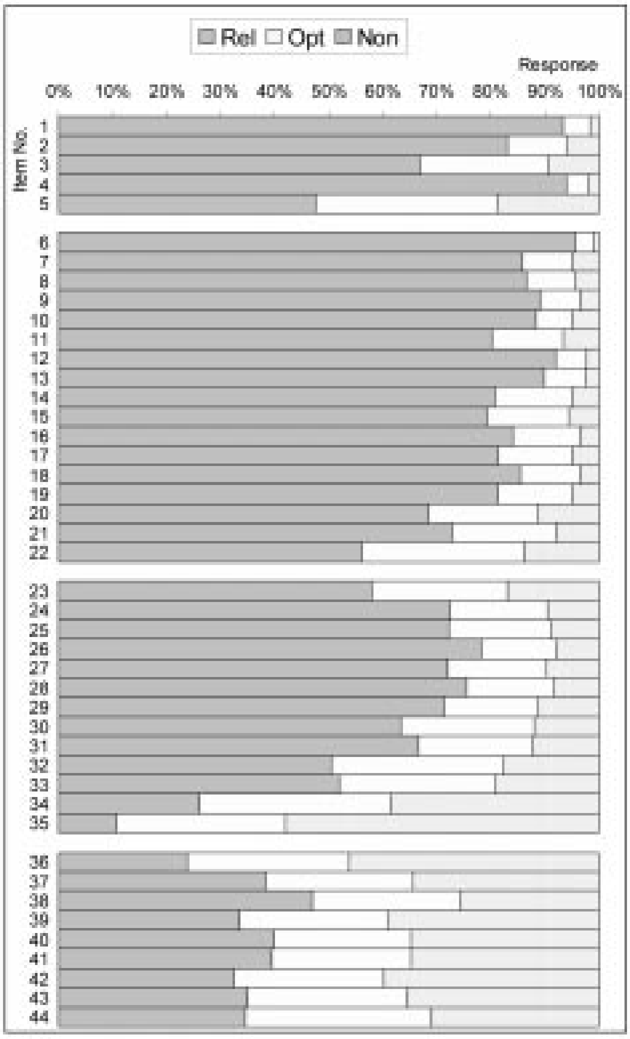

Fig. 3. Distribution of 'relevant', 'optional' and 'not relevant' ratings given to individual items in the survey.

gave the highest relevant rating to all sets. In all regions, 50% or more of the faculty rated Physics II as relevant, except for NCTR. On the other hand, relevant ratings by faculty for Physics III were less than 50% in each region.

The distribution of ratings by all the respondents to each survey item is given in Fig. 3.

Item 5 from the general skills and knowledge set, items 34 and 35 from Physics II topics and all items from Physics III topics, were all rated as relevant by less than 50% of the respondents. All other items were rated as relevant by over 50% of all the respondents. On the other hand, item 35, on cosmology, was the only item regarded as not relevant by more than 50% of the respondents.

Table 3. Departmental and regional percentage of 'relevant' responses to individual items. Values of more than 50% are shaded grey

On the whole, both on a departmental and regional basis, faculty rated the general skills and knowledge and Physics I items mostly as relevant. With the exception of CE faculty, and to a lesser extent NCTR and EURO faculty, Physics II was also rated as relevant. In Physics III, however, EE and to some extent EC faculty rated about half the items as relevant, while CE and ME faculty did not rate any of the items as relevant. On a regional basis, only North American faculty demonstrated a positive attitude towards Physics III items, with about half the items rated as relevant.

In the general skills and knowledge set, items 1, 2 and 4, referring to problem solving, instrumentation and laboratory skills and knowledge of classical mechanics respectively, were rated relevant by a significant majority of the respondents. Item 3, on teamwork skills, although also rated as relevant, surprisingly received a markedly lower relevant response in comparison to the former items. This is surprising, since 'teamwork' is a desirable, and even a required, attribute of engineers, frequently emphasised by all professional engineering bodies and accreditation boards. The same attitude was also observed in the responses to the chemistry section of the survey [10].

Item 5, which refers to knowledge of modern physics, received departmental ratings that are unexpected and deserve explanation. While the 28% relevant response from CE faculty is understandable, a relevant response of 46% from ME faculty is unexpectedly high. Conversely, the rele-

Table 3 shows the relevant response percentage to individual items, both departmental and regional.

No	CE	EC	EE	ME	AMER	EURO	NCTR	OTHER	UK	ALL
General Skills and Knowledge										
1	94.1	94.2	90.3	94.2	96.2	85.4	92.8	89.5	100.0	93.4
2	82.4	78.3	83.9	86.4	84.1	85.4	79.5	86.8	80.0	83.1
3	58.8	69.6	75.8	66.0	64.4	68.3	68.7	63.2	76.0	66.8
4	98.8	84.1	95.2	96.1	97.7	90.2	90.4	92.1	96.0	94.0
5	28.2	58.0	64.5	46.6	54.5	53.7	38.6	47.4	32.0	47.6
Physics I										
6	97.6	89.9	96.7	97.1	95.5	97.6	94.0	97.3	96.0	95.6
7	95.3	69.6	80.3	92.2	91.7	80.5	79.5	86.5	84.0	85.8
8	92.9	73.9	85.2	90.3	90.9	80.5	81.9	86.5	88.0	86.5
9	98.8	71.0	88.5	93.2	94.7	80.5	85.4	86.8	88.0	89.0
10	98.8	68.1	88.5	93.2	93.2	80.5	85.4	86.8	88.0	88.4
11	91.8	60.9	77.0	85.4	84.1	68.3	80.5	84.2	72.0	80.2
12	96.5	81.2	93.5	94.2	93.9	92.7	88.0	89.5	96.0	91.8
13	92.9	76.8	93.4	94.2	93.2	87.8	87.8	84.2	92.0	89.9
14	89.4	56.5	82.0	89.3	87.9	73.2	76.8	73.7	80.0	80.8
15	88.2	59.4	75.4	87.4	82.6	70.7	76.8	78.9	84.0	79.2
16	87.1	71.0	82.3	91.3	87.9	75.6	81.9	78.9	92.0	84.0
17	83.5	68.1	82.0	88.3	87.1	73.2	76.8	76.3	88.0	81.4
18	96.5	63.8	83.6	92.2	90.2	73.2	86.6	78.9	88.0	85.5
19	85.9	72.5	83.6	82.5	90.2	73.2	72.0	76.3	88.0	81.4
20	81.2	44.9	50.8	84.5	75.8	56.1	61.0	73.7	68.0	68.6
21	72.9	71.0	75.4	72.8	78.8	70.7	61.0	73.7	84.0	73.0
22	46.4	59.4	59.0	60.2	65.6	43.9	47.6	52.6	60.0	56.2
Physics II										
23	56.0	39.1	55.7	73.8	67.9	46.3	47.6	60.5	56.0	58.0
24	64.3	56.5	73.8	89.3	84.0	58.5	63.4	73.7	64.0	72.6
25	64.3	60.9	70.5	87.4	84.0	56.1	64.6	71.1	64.0	72.2
26	51.2	87.0	96.8	83.5	87.8	80.5	63.9	76.3	76.0	78.3
27	46.4	84.1	90.3	73.8	80.9	75.6	56.6	73.7	68.0	72.0
28	51.2	88.4	93.5	75.7	82.4	80.5	62.7	76.3	72.0	75.5
29	41.7	85.5	91.9	73.8	79.4	78.0	53.0	73.7	76.0	71.4
30	33.3	85.5	87.1	58.8	66.4	75.6	52.4	57.9	72.0	63.4
31	35.7	85.5	91.9	64.1	71.8	78.0	53.0	63.2	72.0	66.7
32	33.3	58.0	62.3	52.4	58.0	36.6	37.8	63.2	56.0	50.5
33	33.3	65.2	65.6	50.5	58.8	51.2	39.0	52.6	60.0	52.1
34	13.1	33.3	34.4	27.2	29.8	29.3	22.0	21.1	24.0	26.2
35	10.7	14.5	11.5	7.8	14.5	7.3	8.5	13.2	0.0	10.7
Physics III										
36	17.1	26.5	37.3	19.8	29.5	24.4	20.5	23.7	4.2	23.9
37	17.1	42.6	53.3	43.6	51.2	34.1	28.2	28.9	24.0	38.3
38	28.0	52.9	63.3	48.5	57.4	51.2	35.9	44.7	24.0	46.9
39	15.9	41.2	50.0	32.7	48.1	36.6	20.5	23.7	8.0	33.4
40	18.5	51.5	56.7	39.6	55.8	47.5	26.9	23.7	12.0	40.0
41	22.0	51.5	53.3	37.6	53.5	39.0	28.2	36.8	8.0	39.5
42	14.8	47.1	46.7	28.7	42.6	40.0	21.8	28.9	8.0	32.6
43	20.7	42.6	46.7	34.7	49.6	36.6	20.5	23.7	20.0	35.0
44	18.5	47.1	46.7	32.0	48.1	34.1	18.4	31.6	20.0	34.6

vant response from 64.5 % of EE and 58% of EC faculty appear to be too low. A possible explanation for this attitude of ME faculty could be the rapid development of custom-made speciality materials, and their growing use in an increasingly multi-disciplinary engineering profession for the development of advanced, high-tech and mostly nano-scale technology.

In Physics I, with the exception of items 20 and 22, referring to fluid mechanics and sound waves respectively, all items were rated as relevant by significantly more than 50% of faculty on a departmental as well as regional basis.

For item topics in Physics II, the most striking feature is that nuclear physics and cosmology (items 34 and 35) are rated relevant by only about 30% or less of faculty members in all departments and regions. Additionally, two other items, namely 23 and 32, were rated relevant by less than 50% of faculty both from NCTR and EURO regions, and one other item (item 33) was underrated solely by NCTR. From a departmental perspective, CE faculty rated only five items (items 23–26 and 28), referring to thermodynamics, gas theory and basic electricity, as relevant.

For Physics III items, the overall rating is very poor, with the exception of EE, EC and AMER faculty. While on a departmental basis EE and EC faculty rated five (37–41) and three (38, 40 and 41) items, respectively, as being relevant, on a regional basis only AMER faculty rated four (items 37, 38, 40, 41) as relevant. UK faculty consistently rated these items poorly, with a maximum rating of 24%. The most poorly rated item in Physics III was special relativity (item 36). It is somewhat surprising that EE faculty rated item 44, referring to solid state physics, which constitutes an important basis of electronic devices, very poorly.

CONCLUSIONS

These results confirm that, on the whole, engineering faculty consider physics to be an important and integral part of core engineering curricula. However, as might have been expected, there are dramatic variations in the attitudes expressed by respondents on a departmental and regional basis.

The results presented above also show that current attitudes of engineering faculty are in excellent conformity with the SOCRATES Thematic Network E4 guideline articles (a) to (e) given in our introduction. However, with regard to article (f) on the basic principles of quantum theory, present attitudes shown by engineering faculty, even in EE, fall seriously short of meeting this recommendation.

The historically traditional topics of classical physics are highly rated as relevant by all faculty, irrespective of their departmental affiliation or geographical region. However, the requirements of present-day technologies, primarily in the fields of electronics, mechatronics, nano-technology and advanced materials, call for better knowledge and greater competencies based on quantum physics. From this perspective, engineering faculty need to reconsider their attitudes towards quantum physics, and to place greater emphasis on its teaching within engineering curricula. Otherwise, we may see a repetition of history, as was experienced immediately after the Second World War, where engineers will once again be unable to 'sustain productive careers'.

REFERENCES

1. J. W. Prados, Engineering education in the United States: Past, present, and future, *Proc. Int. Conf. Engineering Education*, Rio de Janeiro, 15–20 August, 1998.
2. R. K. Cavin, W. H. Joyner and V. C. Wiggins, A semiconductor industry perspective on future directions in ECE education, *IEEE Transaction on Education*, **46**(4), (2003), pp. 463–466.
3. D. Guycochea, M. Maubert, M. Romero and T. Merchand, Reinforcing the teaching of basic sciences in undergraduate engineering programs and its correlation with teaching sciences of engineering, *Proc. Int. Conf. Engineering Education*, Rio de Janeiro, 15–20 August, 1998.
4. J. Kalousek, J. Dobrovska and K. Stransky, The engineers in the educational system, science, research and metallurgical industry: How to find common language, *Proc. Int. Conf. Engineering Education*, Ostrava/Prague, 10–14 August, 1999.
5. F. C. Berry and P. S. DiPiazza, The future of electrical and computer engineering education, *IEEE Transactions on Education*, **46**(4), (2003), pp. 467–476.
6. L. C. McDermott and E. F. Redish, Resource letter: PER-1: Physics education research, *American Journal of Physics*, **67**(9), (1999), pp. 755–767.
7. G. Heitmann, A. Avdelas and O. Arne, Innovative curricula in engineering education, *E4 Thematic Network: Enhancing Engineering Education in Europe, Volume C*, Florence: Firenze University Press (2003).
8. D. C. Giancoli, *Physics for Scientists and Engineers*, 3rd edition, Prentice Hall, Upper Saddle River, NJ (2000).
9. R. A. Serway and R. J. Beichner, *Physics for Scientists and Engineers with Modern Physics*, 5th edition, Saunders College Publishing, Fort Worth (2000).
10. M. Garip, E. Erdil and A. Bilsel, Engineering faculty attitudes to general chemistry courses in engineering curricula (submitted for publication).

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