

THE DESIGN OF A THEORETICAL MODEL AND CRITERIA
FOR THE CONSTRUCTION OF A CURRICULUM
FOR PHYSICAL SCIENCE

with special reference to the teaching
of Physical Science in the Cape Province

by

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PART III: A COMPARATIVE EVALUATION OF THE CURRICULUM FOR PHYSICAL SCIENCE
IN PROVINCIAL HIGH SCHOOLS OF THE CAPE OF GOOD HOPE

CHAPTER 11

THE METHODS OF INVESTIGATION

1. TESTING A MODEL AND CRITERIA FOR CURRICULUM DESIGN

1.1 Introductory

Much has been written on the evaluation of curricula but the testing and evaluation of models for curriculum design and their accompanying criteria, seem to be a completely new field. This being so, any first effort at the design and application of such a testing programme will only be preliminary and tentative, and will probably only provide indications as to the possible viability of the model under consideration. Further developments in the procedures and techniques of evaluation in this field, as well as application of the model to a wider range of subjects and to different levels of education, will be necessary before any valid conclusions about the value and applicability of the model can be arrived at. It is also expected that a thorough testing and evaluation programme will be a relatively long-term process during which adaptations and modifications to the original model and criteria may be made in order to improve and refine both the original concept as well as its finer details. It is also possible, however, that the non-feasibility of the model and criteria may become evident at an early stage of testing and that the model may thus be rejected.

1.2 The design of an initial feasibility study

The success of a curriculum, and therefore of the model and criteria on which it is based, can only be properly evaluated in a practical situation. Obviously, then, the proper procedure would be to design a curriculum based on the model and criteria under test, to implement this curriculum and to subject it to a thorough evaluation programme.

Initially it may be advisable to limit the programme to a small-scale investigation, e.g. by designing a part-curriculum for only one component or unit of the subject. For Physical Science, for instance, such a pilot study could be carried out on a part-curriculum designed for one component of the physics section (such as mechanics) and one component of the chemistry section (such as chemical equilibrium). Depending on the results and feedback of such a pilot study, a full investigation may then be designed and carried out.

1.2.1 Practical limitations

In the highly centralized South African education system with its prescribed syllabuses and external final examinations, the procedure outlined above will be extremely difficult to put into practice for a subject such as Physical Science which is taught in the senior secondary school phase. The main limitations are the following:

1. The prescribed content of the official syllabuses, or of components of these syllabuses, must be retained. It is possible to add to this content but no prescribed content may be omitted.
2. A programme of minimum practical work is prescribed and forms part of the syllabuses. These experiments must be retained in the experimental curriculum and the inclusion of new teaching-learning activities is thus severely restricted.
3. The departments of education only allow research programmes to be conducted during the last school term in highly exceptional cases, e.g. in the case of an official, national test programme.
4. The pupils involved have to sit for external examinations set by a provincial education department. This factor, together with the previous one, practically excludes the possibility of involving pupils in their final school year and limits the investigation to the first two years of the three years at school. This situation presents insuperable problems in the application of the criteria for the selection and organization of content as well as in the design of final pupil assessment programmes.

5. For science subjects the design of suitable teaching-learning activities involves the preparation of text materials, instructional aids of various kinds and laboratory equipment, apparatus and materials. These can only be effectively produced by a team of specialists and teachers backed by an institution or body with sufficient funds at its disposal.
6. Permission to conduct private, non-official investigations of the type envisaged here is usually limited to two to four schools only. This condition makes it impossible to obtain a sample representative of the different school types and settings.
7. In addition to the permission from the education departments, permission must also be obtained from the principals of the selected schools. Principals may prefer not to participate even though prior permission has been obtained from the education department.
8. At the time of this study, the Cape Education Department was itself conducting an investigation into syllabus experimentation and internal examining.

1.2.2 Comparative evaluation - a compromise

The limitations imposed by the regulations to which the education authorities are subject made it impossible to design a feasibility study along the lines suggested in Section 1.2 above. However, the Cape Education Department granted the author permission to circulate questionnaires to pupils and teachers of all high schools in the Cape Province offering Physical Science as a subject, provided that these questionnaires be completed during the first, second or third school terms.

Eventually all attempts to evaluate the model in all its aspects had to be abandoned and it was decided to limit the exercise to an investigation into the application of the criteria only.

This decision left only a few unsatisfactory options, such as concentrating on the criteria for a single element, e.g. selection of content; to design a curriculum according to the model and those criteria applicable under such circumstances and to compare the product with the existing syllabus; or to evaluate the existing syllabus by means of the available evaluation techniques as well as by applying the criteria to the different elements and to compare the results of the two evaluations. In order to involve as many curriculum elements in the investigation as possible, the latter process of comparative evaluation was adopted.

2. THE METHODS AND PROCEDURES EMPLOYED

2.1 The two kinds of evaluation

2.1.1 The syllabus for Physical Science as a curriculum

A syllabus was defined as a selection and organization of the content of a subject (Chapter 2, Section 1.2.10), whereas a curriculum provides a description and systematic arrangement of the content, activities, methods and evaluation procedures for a subject.

In the South African context, then, the "curriculum" is the result of the contributions of a number of independent bodies and persons: The syllabus (content and organization), the practical work (which may form part of the teaching-learning activities) and the form, contents, nature and duration of the final external examination, are prescribed by the education authorities. The text materials (textbook, laboratory manual) are produced by individual authors or groups of authors and published commercially. The methodology is decided upon by the teachers themselves, although Departmental guides and directives¹ and the requirements of and guidance given by Inspectors of Education, may greatly influence the methods of teaching. In practice the syllabus content is largely interpreted by the textbook authors and the external examiners.

To relate this status quo to curriculum criteria, those curriculum components not directly included in the prescribed syllabuses were, wherever possible, also taken into consideration in the valuation programme.

2.1.2 The criterion-independent evaluation

This component of the comparative evaluation programme involved the following:

1. Questionnaires to teachers²

By means of these questionnaires information was obtained on -

- (a) the objectives;
- (b) the content;
- (c) the methodology, including the availability and suitability of curriculum materials.

2. Questionnaires to pupils³

These questionnaires were completed by pupils in their final school year and concentrated on gaining information relating to

- (a) the objectives;
- (b) the effectiveness of methods;
- (c) the ability of pupils to master aspects of the content;
- (d) aspects of evaluation (pupil assessment).

3. Questionnaires to university lecturers⁴

Questionnaires were sent to university lecturers in physics and chemistry involved in the teaching of first year students.

Information was requested on

- (a) the objectives;
- (b) the content;
- (c) the abilities of students which relate directly to the aims of the school syllabus;
- (d) the correctness of the content of the textbooks used in schools.

4. Observation of classroom practice⁵

This observation was carried out in high schools, technical high schools and agricultural high schools in the Cape Province over a two year period from October 1975 to June 1977.

5. Analysis of examination papers

The examination papers of the Cape Education Department for Physical Science Higher Grade and Physical Science Standard Grade for the external examinations of November 1976 and November 1977 were analysed to determine

- (a) the types of abilities and knowledge assessed; and
- (b) the relationship between stated syllabus objectives and the examination questions.

2.1.3 The criterion-based evaluation

The second component of the evaluation consisted of applying the criteria developed in Chapters 6 to 10 to elements of the "curriculum" for Physical Science, i.e. to the official syllabus, the methods generally employed in the teaching and to the pupil assessment aspect of the evaluation process. The criterion-based evaluation was thus directed at

1. the official objectives;
2. the content;
3. the organization of the content;
4. aspects of the methods and procedures of evaluation.

Problems encountered in the application of certain criteria, e.g. the criterion of interest with respect to the selected content, will be discussed in the appropriate chapters.

2.2 The comparison of the evaluation results

The methods outlined above unfortunately do not lend themselves to the statistical comparison of quantitative results. However, the main purpose of the investigation is to establish whether the criteria can be successfully applied to an existing curriculum and whether the results would be comparable to those obtained in a criterion-independent evaluation. A large measure of agreement in the outcomes of the two evaluations will be interpreted as a preliminary and tentative indication of the validity and applicability of the criteria and that a more comprehensive and rigorous investigation of the complete model is indicated.

A conclusion of this nature - whether positive or negative - is based on the assumption that the criterion-independent evaluation used is a suitable instrument which yields sufficiently valid results to serve as a basis for comparison. Within the limitations of, and those imposed on, the present study, only the following techniques of ensuring some degree of validity were available, viz.

1. triangulation, i.e. obtaining the same information from more than one source;
2. using as large a sample as is practically possible and feasible for each of the questionnaires as well as for the observation of teaching.

3. THE CRITERION-INDEPENDENT EVALUATION

3.1 The questionnaire for teachers

3.1.1 According to Steadman⁶ the construction of questionnaires should be undertaken with the same kind of stringency that is expected in the construction of attitude scales and attainment tests, and he suggests the following guidelines based on the works of Moser⁷ and Oppenheim⁸:

1. The questions asked should be ones that the teacher (pupil, etc.) can answer.

2. Observe the same kind of rules which govern the construction of an attitude scale, e.g. do not use four or more grades, say A to D, for the expression of approval. Everyone will then answer B or C.
3. Consider carefully the sample from which the opinions are drawn.
4. Arrange to cross-check opinions against the opinions of others, e.g. teachers' with pupils'.
5. Use more than one method of collecting information.

The following procedures were adopted in the construction of the questionnaires:

1. For each of the questionnaires for teachers, pupils and university lecturers, a draft questionnaire was compiled and tested in three schools, involving 30 pupils, and in two universities (involving 15 lecturers), respectively. From the results of this pilot study the questions were finalised in the form eventually used.
2. Questions were constructed in such a way that responses could be limited to (a) a simple choice between a "yes" or "no" answer, or (b) to a choice from only three possibilities such as "high interest value", "average interest value" and "low interest value" or "essential", "desirable" and "unnecessary". The only exception was the arrangement of seven syllabus aims in order of decreasing importance according to the teachers' opinions.
3. An effort was made to use a very large sample involving all school types and settings and the full range of practising teachers.
4. Wherever possible the same aspects were included in more than one questionnaire in order to obtain information on each aspect from two or three different sources.

3.1.2 The range of questions

Questions on the following aspects were put to teachers:

1. General information on the sex, qualifications and experience of the teachers.
2. Information on the school type, school setting and class size.
3. Information on aids (including textbooks) and facilities available.
4. The length of the syllabus.
5. The degree of difficulty in comparison with other school subjects and the relative difficulty of the two components, namely physics and chemistry.
6. The interest value of the syllabus and of each topic included in the syllabus.
7. The aims and objectives of the syllabus.
8. The content of the syllabus.
9. The teaching methods used.

Each of the areas covered by 3 to 9 above, will be discussed in detail in the appropriate chapters.

3.1.3 The nature and size of the sample

Questionnaires were sent to all high schools in the Cape Province which offered Physical Science as a subject in the third year of the senior secondary phase (Standard 10) and which entered for the Cape Senior Certificate Examination in November/December 1978. Schools in Transkei, which fall under the Cape Education Department; in Griqualand East which were transferred to Natal in April 1978; and in Walvis Bay, which are politically part of the Cape Province but were administered by the Administration of South West Africa up to the end of 1977; were excluded. Private schools, not administered by the Cape Education Department but which enter candidates for the Cape Senior Certificate, were included. Except for one high school for Chinese, all the schools are schools for whites. Technical High Schools and Agricultural High Schools were included.

Since participation of individual schools was voluntary, not all questionnaires were returned. The nature and size of the final sample are given in TABLE 11.1.

(a) Size and distribution of sample according to SCHOOL TYPE

| School type | Cape schools offering Physical Science as a subject in Std 10 in 1978 | | Schools represented in the sample | |
|------------------------------|---|------------|-----------------------------------|------------|
| | Number | Percentage | Number | Percentage |
| 1. High Schools | 206 | 93,2 | 152 | 93,3 |
| 2. Agricultural High Schools | 5 | 2,3 | 3 | 1,8 |
| 3. Technical High Schools | 10 | 4,5 | 8 | 4,9 |
| TOTAL | 221 | 100,0 | 163 | 100,0 |

TABLE 11.1 TYPES OF HIGH SCHOOLS OFFERING PHYSICAL SCIENCE IN STANDARD 10: REPRESENTATION IN THE SAMPLE

The remarkable similarity of distribution in the sample and the total population may be ascribed to the large size of the sample, viz. 73,8% of the population.

(b) Size and distribution of sample according to LOCALITY

For the purpose of this analysis the schools were classified as urban, i.e. city and suburban schools, and rural, i.e. schools situated in country towns and areas. The relevant data are summarised in TABLE 11.2

| Locality of the schools | Cape schools offering Physical Science as a subject in Std 10 in 1978 | | Schools represented in the sample | |
|-------------------------|---|------------|-----------------------------------|------------|
| | Number | Percentage | Number | Percentage |
| 1. Urban | 67 | 30,3 | 46 | 28,2 |
| 2. Rural | 154 | 69,7 | 117 | 71,8 |
| TOTAL | 221 | 100,0 | 163 | 100,0 |

TABLE 11.2 LOCALITIES OF HIGH SCHOOLS OFFERING PHYSICAL SCIENCE IN STANDARD 10: REPRESENTATION IN THE SAMPLE

Schools situated in the following areas were classified as urban:

- (a) Cape Town and suburbs (Cape School Board and Parow School Board);
- (b) Port Elizabeth and suburbs (Port Elizabeth School Board);
- (c) East London and suburbs (East London School Board); (d) Kimberley.

The distribution of schools according to locality is highly satisfactory. Since most English medium schools are situated in urban areas, the slight shift of 2% in favour of rural schools is also reflected in the school type according to the medium of instruction. The relevant data are supplied in TABLE 11.3.

(c) Size and distribution of sample according to MEDIUM OF INSTRUCTION

Only three classification types were considered for this analysis, viz. (a) Afrikaans medium (including mainly Afrikaans medium); (b) English medium (including mainly English medium); (c) parallel medium. ("Mainly Afrikaans medium" and "mainly English medium" schools are those schools which are not officially single medium schools but where the other language group is not represented or is represented by one or two pupils only. In these schools the medium of instruction is in practice either English or Afrikaans.)

| Medium of instruction | Cape schools offering Physical Science as a subject in Std 10 in 1978 | | Schools represented in the sample | |
|-----------------------|---|------------|-----------------------------------|------------|
| | Number | Percentage | Number | Percentage |
| 1. Afrikaans | 133 | 60,2 | 102 | 62,6 |
| 2. English | 47 | 21,3 | 32 | 19,6 |
| 3. Parallel | 41 | 18,6 | 29 | 17,8 |
| TOTAL | 221 | 100,1 | 163 | 100,0 |

TABLE 11.3 MEDIUM OF INSTRUCTION IN HIGH SCHOOLS OFFERING PHYSICAL SCIENCE IN STANDARD 10: REPRESENTATION IN THE SAMPLE

(d) Size and distribution of sample according to SEX OF PUPILS

Here, too, three school types are represented in the population, viz., (a) schools for boys; (b) schools for girls; (c) co-educational schools.

| School type according to sex | Cape schools offering Physical Science as a subject in Std 10 in 1978 | | Schools represented in the sample | |
|------------------------------|---|------------|-----------------------------------|------------|
| | Number | Percentage | Number | Percentage |
| 1. Boys' schools | 29 | 13,1 | 21 | 12,9 |
| 2. Girls' schools | 17 | 7,7 | 13 | 8,0 |
| 3. Co-educational | 175 | 79,2 | 129 | 79,1 |
| TOTAL | 221 | 100,0 | 163 | 100,0 |

TABLE 11.4 SINGLE SEX AND CO-EDUCATIONAL HIGH SCHOOLS OFFERING PHYSICAL SCIENCE IN STANDARD 10: REPRESENTATION IN THE SAMPLE

Again, the sample shows an excellent agreement with the original population.

(e) Size and distribution of sample according to CLASS SIZE

School sizes in the Cape Province vary considerably within the range of 40+ to 900+ pupils enrolled from standards 6 to 10. The number of pupils offering Physical Science in Standard 10 varies accordingly, viz. from a single pupil (4 schools) to a maximum of 113 in one school. The term "class size" is used here to indicate the number of pupils taking Physical Science as a subject in Standard 10 in 1978 and not the actual size of the teaching unit or group.

| Class sizes expressed as number of pupils | Cape schools offering Physical Science as a subject in Std 10 in 1978 | | Schools represented in the sample | |
|---|---|------------|-----------------------------------|------------|
| | Number | Percentage | Number | Percentage |
| 1. 1 - 10 | 103 | 46,6 | 82 | 50,3 |
| 2. 11 - 20 | 44 | 19,9 | 32 | 19,6 |
| 3. 21 - 30 | 32 | 14,5 | 21 | 12,9 |
| 4. 31 - 40 | 12 | 5,4 | 7 | 4,3 |
| 5. 41 - 50 | 13 | 5,9 | 8 | 4,9 |
| 6. 51 - 60 | 5 | 2,3 | 5 | 3,1 |
| 7. 61 - 70 | 6 | 2,7 | 4 | 2,5 |
| 8. 71 - 80 | 3 | 1,4 | 3 | 1,8 |
| 9. 81 - 90 | 0 | 0,0 | 0 | 0,0 |
| 10. 91 - 100 | 2 | 0,9 | 1 | 0,6 |
| 11. >100 | 1 | 0,5 | 0 | 0,0 |
| TOTAL | 221 | 100,1 | 163 | 100,0 |

TABLE 11.5 DIFFERENT CLASS SIZES FOR PHYSICAL SCIENCE IN STANDARD 10: REPRESENTATION IN THE SAMPLE

The small variations in the class sizes represented in the sample do not distract from the similarity in general trend and distribution. The slightly higher representation of small class sizes (1 to 10 pupils) of 3,7% may be ascribed to the larger representation of rural schools in the sample.

(f) Size and distribution of sample according to NUMBER OF TEACHERS

In the larger schools more than one teacher may be involved in the teaching of Physical Science in Standard 10. In the case of these schools questionnaires were sent to each teacher involved in the teaching of a Standard 10 class. The number of teachers which completed the questionnaire, is given in TABLE 11.6(a).

| Number of teachers involved in teaching Physical Science in Std 10 in 1978 | Number of teachers in the sample | Percentage |
|--|----------------------------------|------------|
| 233 | 171 | 73,4 |

TABLE 11.6(a) NUMBER OF TEACHERS INVOLVED IN THE TEACHING OF PHYSICAL SCIENCE IN STANDARD 10 IN 1978: REPRESENTATION IN THE SAMPLE

Data on the qualifications, teaching experience, sex and home language of this teacher population for 1978 were not yet available from official sources at the time of writing and only data derived from the questionnaire are thus presented in TABLE 11.6(b).

| | | | | | | |
|--|-------------------|---------------|---------------|----------------|-------------|-----------|
| Sex of teacher | Male | | | Female | | |
| | 86,5% (148) | | | 13,5% (23) | | |
| Qualifications | University degree | | | No degree | | |
| | 94,7% (162) | | | 5,3% (9) | | |
| Number of university courses passed in - | 0 | 1 | 2 | 3 | Higher | |
| (a) Physics | 1,8% (3) | 35,1% (60) | 21,1% (36) | 35,7% (61) | 2,3% (4) | |
| (b) Chemistry | 1,2% (2) | 25,1% (43) | 25,7% (44) | 40,4% (69) | 4,1% (7) | |
| Year degrees were obtained | Since 1970 | 60-69 | 50-59 | 40-49 | 30-39 | Before 30 |
| | 21,1% (36) | 52,0% (89) | 11,1% (19) | 7,6% (13) | 2,9% (5) | 0% (0) |
| University* where degree was obtained | Stell. | U.C.T. | Rhodes | U.P.E. | Pret. | |
| | 62,6% (107) | 9,4% (16) | 6,4% (11) | 2,3% (4) | 0,6% (1) | |
| | Potch. | O.F.S. | Natal | Other | | |
| | 3,5% (6) | 5,8% (10) | 2,3% (4) | 1,8% (3) | | |
| Professional teachers' diploma/certificate | Diploma/Cert. | | | No prof. qual. | | |
| | 97,1% (166) | | | 2,3% (4) | | |

* Stell. = University of Stellenbosch; U.C.T. = University of Cape Town; Rhodes = Rhodes University, Grahamstown; U.P.E. = University of Port Elizabeth; Pret. = University of Pretoria; Potch. = Potchefstroom University for C.H.E.; O.F.S. = University of the Orange Free State, Bloemfontein; Natal = University of Natal, Durban and Pietermaritzburg; Other = Overseas universities.

TABLE 11.6(b) ADDITIONAL INFORMATION ON THE COMPOSITION OF THE SAMPLE OF TEACHERS

3.2 The questionnaire for pupils

3.2.1 The range of questions

Questions were put on aspects of the following:

1. School type and setting.
2. Sex, age, home language and course of study of the pupil.
3. Attitudes towards science, viz. like/dislike for the subject; interest in science.
4. Interest value of the syllabus.
5. Degree of difficulty compared to other school subjects.
6. Possible effects of syllabus on career choice.
7. Effectiveness of and preference for specific teaching methods and aids.
8. Attainment of the aims and objectives.
9. Pupil assessment (examinations).

After the initial trial of a draft questionnaire in three schools using a sample of 30 pupils, questions on the following were omitted from the final questionnaire:

1. Opinions on the interest value and degree of difficulty of the separate syllabus topics;
2. the sequence and organization of the content.

The reason for this is that the initial trials showed that pupils lose interest or become fatigued when confronted with lengthy lists of material, such as syllabus topics, and tend to choose the responses requiring the least amount of thinking and consideration, e.g. "uncertain" or "doubtful".

3.2.2 The nature and size of the sample

Questionnaires for pupils were sent to all 221 schools selected for teacher questionnaires (see Section 3.1.3). The pupil population thus included all high schools which had entered for the Cape Senior Certificate Examination in 1978 with the exception of the small number of schools in Griqualand East, Walvis Bay, South West Africa and Transkei.

(a) Method of selection of the sample:

During the initial trial a table of random numbers⁹ was used to select the sample of 30 pupils (10 from each school involved). After discussions with the teachers it was decided not to use this method in the main investigation. As schools usually have numbered class lists available, the following selection procedure was designed:

1. A sample of up to 10 pupils, drawn from the class taught by the participating teacher (Section 3.1.3) was used.
2. Teachers were asked to list the surnames of the pupils offering Physical Science Higher Grade and Standard Grades alphabetically, with Higher and Standard Grades and boys and girls (where applicable) mixed. The names on the list were then to be numbered from 1 onwards, in numerical sequence.
3. Selection was done as follows:

(a) Class size: 1 to 10 pupils

All pupils completed the questionnaire.

(b) Class size: 11 to 20 pupils

Starting at number 1, every second pupil, i.e. 1, 3, 5, 7, etc., was selected. Selection was repeated, if necessary, by doing a second count starting from number 2, until 10 pupils were selected.

Example (for a class of 16 pupils):

| | | | | | | | | | | | | | | | | |
|------------|---|---|---|---|---|---|---|---|---|----|----|----|----|----|----|----|
| Pupils: | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
| 1st count: | x | | x | | x | | x | | x | | x | | x | | x | |
| 2nd count: | | | | | | | | | | | | | | | | |

- (c) For classes of 21 to 30, 31 to 40, etc. pupils, the same procedure was used, counting every third, fourth, etc. pupil, respectively.

The main disadvantage of the sampling method used, is that pupils from small schools, with classes ranging from 1 to 20 pupils, may be over-represented in the sample. To offset this, questionnaires were sent to teachers rather than to schools. In this way two or more samples of 10 pupils each would be obtained from the larger schools.

(b) Size of sample in comparison with selected population and total population

The total population is made up of all pupils offering Physical Science Higher Grade and Standard Grade in Standard 10 in 1978 in the 221 schools.

The selected population comprises the possible maximum sample selected according to the procedure outlined in the previous section.

The sample is the total number of completed questionnaires received.

The representation of the sample in the total population and the selected population is summarised in TABLE 11.7.

| Total population (A) | Selected population (B) | | Sample | | |
|----------------------|-------------------------|-----------------|--------|-----------------|-----------------|
| | Number | Percentage of A | Number | Percentage of A | Percentage of B |
| 4 244 | 1 794 | 42,3 | 1 219 | 28,7 | 67,9 |

TABLE 11.7 TOTAL POPULATION AND SELECTED POPULATION OF PUPILS TAKING PHYSICAL SCIENCE IN STD 10: RELATIVE SIZE OF THE SAMPLE

(c) Size and distribution of sample according to SCHOOL TYPE

| School type | Pupils taking Physical Science in Std 10 in 1978 in the different types of schools | | | |
|------------------------------|--|------------|--------|------------|
| | Total population | | Sample | |
| | Number | Percentage | Number | Percentage |
| 1. High Schools | 3 865 | 91,1 | 1 110 | 91,0 |
| 2. Agricultural high schools | 27 | 0,6 | 19 | 1,6 |
| 3. Technical high schools | 352 | 8,3 | 90 | 7,4 |
| TOTAL | 4 244 | 100,0 | 1 219 | 100,0 |

TABLE 11.8 PUPILS OFFERING PHYSICAL SCIENCE IN THE DIFFERENT SCHOOL TYPES: REPRESENTATION IN THE SAMPLE

The pupils in the sample are thus remarkably representative of the total population according to the type of school.

(d) Size and distribution of sample according to LOCALITY

| Locality of the schools | Pupils taking Physical Science in Std 10 in schools of different localities | | | |
|-------------------------|---|------------|--------|------------|
| | Total population | | Sample | |
| | Number | Percentage | Number | Percentage |
| 1. Urban | 1 926 | 45,4 | 491 | 40,3 |
| 2. Rural | 2 318 | 54,6 | 728 | 59,7 |
| TOTAL | 4 244 | 100,0 | 1 219 | 100,0 |

TABLE 11.9 NUMBER OF PUPILS IN URBAN AND RURAL HIGH SCHOOLS: REPRESENTATION IN THE SAMPLE

The representation in the sample of pupils from urban schools is too low by 5,1% and vice versa. The possible reason for this has been explained in Section 3.1.3, paragraph (b). The same explanation applies to the deviations in medium of instruction shown in TABLE 11.10 below.

(e) Size and distribution of sample according to MEDIUM OF INSTRUCTION

| Medium of instruction | Pupils taking Physical Science in Std 10 in 1978 instructed through different language media | | | |
|-----------------------|--|------------|--------|------------|
| | Total population | | Sample | |
| | Number | Percentage | Number | Percentage |
| 1. Afrikaans | 1 698 | 40,0 | 607 | 49,8 |
| 2. English | 1 623 | 38,2 | 326 | 26,7 |
| 3. Parallel | 9 | 21,8 | 286 | 23,5 |
| TOTAL | 4 244 | 100,0 | 1 219 | 100,0 |

TABLE 11.10 PUPILS INSTRUCTED THROUGH DIFFERENT LANGUAGE MEDIA: REPRESENTATION IN THE SAMPLE

Although pupils from English medium schools are under-represented by 11,5% the type of questions asked by the questionnaire are independent of factors related to language of instruction. On this basis the sample may be considered to be representative of the total school population.

(f) Size and distribution of sample according to SYLLABUS GRADE

Physical Science is offered on two grades, viz. Higher Grade and Standard Grade. The Standard Grade syllabus is essentially a "diluted" version of the Higher Grade one, i.e. the same units in physics and chemistry are covered by both but for the Standard Grade some topics or parts of topics within a unit are omitted. The final external examinations for the two grades also differ in emphasis. According to a guide for teachers¹⁰, differentiation in testing is based on a simplified version of Bloom's taxonomy, viz.

- (a) knowledge;
- (b) comprehension;
- (c) application;
- (d) higher abilities.

The examination papers for both grades contain questions testing all four abilities, but the emphasis in the Standard Grade is more on (a) and (b), whereas in the Higher Grade papers (c) and (d) receive relatively more attention.

| Syllabus grade | Pupils offering Physical Science in Std 10 on the Higher and Standard Grades | | | |
|-------------------|--|------------|--------|------------|
| | Total population | | Sample | |
| | Number | Percentage | Number | Percentage |
| 1. Standard Grade | 1 192 | 28,1 | 360 | 29,5 |
| 2. Higher Grade | 3 052 | 71,9 | 859 | 70,5 |
| TOTAL | 4 244 | 100,0 | 1 219 | 100,0 |

TABLE 11.11 PUPILS OFFERING PHYSICAL SCIENCE ON THE HIGHER GRADE AND STANDARD GRADE: REPRESENTATION IN THE SAMPLE

(g) Other relevant factors

Other factors which may have had an effect on the validity of the sample are (1) the sex of the pupils; (2) their home language; (3) their average age; (4) whether they followed a course leading to matriculation exemption (university entrance) or not. This data was not available for the total population of Standard 10 pupils offering Physical Science as a subject. In the following summary (TABLE 11.12) the figures in brackets used for comparison, refer to preliminary statistics for all the pupils enrolled in Standard 10 in Cape Provincial High Schools.

| | Sample (N = 1 219) | | Total school population |
|----------------------------------|-----------------------|------------|-------------------------------------|
| | Number | Percentage | Approx. percentage |
| 1. <u>SEX</u> | | | (High school) |
| Boys | 863 | 70,8 | 51,2 |
| Girls | 356 | 29,2 | 48,8 |
| 2. <u>HOME LANGUAGE</u> | | | (Standard 10 pupils) |
| Afrikaans | 750 | 61,5 | (61,0) |
| English | 383 | 31,4 | (32,3) |
| Both | 67 | 5,5 | (1,7) |
| Other | 19 | 1,6 | (5,0) |
| | | 7,1 | (6,7) |
| 3. <u>AGE</u> | | | (Standard 10 pupils) |
| 15 | 0 | 0,0 | (<0,1) |
| 16 | 25 | 2,0 | (17,1) |
| 17 | 825 | 67,2 | (63,5) |
| 18 | 345 | 28,3 | (16,5) |
| 19 | 17 | 1,4 | } (2,8) |
| 19+ | 7 | 0,6 | |
| | 24 | 2,0 | |
| Average age | 17,3 | - | (17,52) (Median) |
| 4. <u>COURSE OF STUDY</u> | | | (Passes, 1977 final examination) |
| Matric | 1 042 | 85,5 | (40,5) |
| Non-matric | 177 | 14,5 | (59,5) |

TABLE 11.12 ADDITIONAL INFORMATION ON THE COMPOSITION OF THE SAMPLE

Although comparable statistics on the population of pupils offering Physical Science in 1978 are not available, the sample is sufficiently representative to draw the following conclusions:

- (a) Physical Science is more popular as a school subject among boys than girls.
- (b) Pupils offering Physical Science are on the average slightly younger than the median of the school population.
- (c) More pupils offering Physical Science attempt the matriculation exemption course (university entrance) compared to the total population of Standard 10 pupils.

3.2.3 The representativeness of the sample

In the absence of a rule-of-thumb method for checking the representativeness of a sample in educational research, one has to resort to logical considerations. The procedure recommended by statisticians is to describe the sample as completely as possible with regard to the known characteristics of the population from which it is drawn. If the sample proves to be typical of the population in several variables in nature and composition, it is safe to assume that it is representative. It is, however, necessary to describe the sample and how it was drawn as fully as possible in order to be able to evaluate the research.

The sample of pupils drawn for this investigation comprises 28,7% of the total population of pupils offering Physical Science in Standard 10 in 1978 and is typical of this population in respect of (a) school type and (b) the different syllabus grades (Higher Grade and Standard Grade). It deviates slightly (5,1%) from the sample in respect of the locality of the schools and considerably (9,8%) in respect of medium of instruction. Since the number of schools giving instruction through the different media is highly representative of the universe (TABLE 11.3) this large deviation may be ascribed to the fact that samples of only 10 or 20 pupils have been drawn from the larger urban English schools, whereas the samples drawn from the smaller rural Afrikaans schools very often also comprise the total Physical Science population of these schools.

3.3 The questionnaire for university lecturers

3.3.1 The range of questions

Questions were put on the following:

1. General information: name of university; the department (physics or chemistry); medium of instruction; number of years of experience in teaching first year students in physics or chemistry.
2. Acquaintance with school physics and chemistry, with respect to (a) the syllabuses; (b) the final examination papers; (c) the textbooks generally used in schools.
3. Correctness of those school textbooks with which they are familiar.
4. The most common weaknesses in understanding, knowledge and skills in physics and chemistry of first year students.
5. The aims and objectives of physics and chemistry teaching at school.
6. The content of the syllabuses.

3.3.2 The nature, composition and size of the sample

Questionnaires were sent to lecturers of first year students in the departments of physics and chemistry of each of the universities listed in TABLE 11.13. All South African universities for whites, i.e. those which may draw students from provincial high schools in the Cape Province, were selected.

Five questionnaires were sent to each university department of physics and chemistry. Some of the smaller universities may, however, have fewer than five lecturers directly involved in the teaching of first year students in physics and chemistry.

Although these universities draw students from all provinces and departments of education, the syllabuses for Physical Science of the education departments are all based on the common core syllabuses of the Joint Matriculation Board.¹⁰ Thus the various syllabuses are virtually identical in aims and content, the only major differences being in the prescribed practical work.

| UNIVERSITY | QUESTIONNAIRES RECEIVED | | | | | |
|--------------------------------------|-------------------------|-------------|-----------|-------------|-----------|--------------|
| | PHYSICS | | CHEMISTRY | | TOTAL | |
| | Number | % | Number | % | Number | % |
| 1. Cape Town (E) | 4 | 14,3 | 3 | 13,6 | 7 | 14,0 |
| 2. Free State (A) | 3 | 10,7 | 0 | 0,0 | 3 | 6,0 |
| 3. Natal (Durban) (E) | 2 | 7,1 | 4 | 18,2 | 6 | 12,0 |
| 4. Natal (Pieter- maritzburg) (E) | 2 | 7,1 | 0 | 0,0 | 2 | 4,0 |
| 5. Port Elizabeth (AE) | 0 | 0,0 | 0 | 0,0 | 0 | 0,0 |
| 6. Potchefstroom (A) | 4 | 14,3 | 3 | 13,6 | 7 | 14,0 |
| 7. Pretoria (A) | 1 | 3,6 | 1 | 4,5 | 2 | 4,0 |
| 8. Rand Afrikaans (A) | 2 | 7,1 | 0 | 0,0 | 2 | 4,0 |
| 9. Rhodes (E) | 4 | 14,3 | 4 | 18,2 | 8 | 16,0 |
| 10. Stellenbosch (A) | 3 | 10,7 | 4 | 18,2 | 7 | 14,0 |
| 11. Witwatersrand (E) | 3 | 10,7 | 3 | 13,6 | 6 | 12,0 |
| TOTAL | 28 | 99,9 | 22 | 99,9 | 50 | 100,0 |

TABLE 11.13 COMPOSITION OF THE SAMPLE ACCORDING TO UNIVERSITIES

(A: Afrikaans medium; E: English medium;

AE: Both media).

Nature and composition of the sample:

| | NUMBER OF LECTURERS | | | | | |
|---|---------------------|------|-----------|------|--------|------|
| | PHYSICS | | CHEMISTRY | | TOTAL | |
| | Number | % | Number | % | Number | % |
| 1. MEDIUM OF INSTRUCTION: | | | | | | |
| Afrikaans | 13 | 46,4 | 8 | 36,4 | 21 | 42,0 |
| English | 15 | 53,6 | 14 | 63,6 | 29 | 58,0 |
| Both | 0 | 0,0 | 0 | 0,0 | 0 | 0,0 |
| 2. EXPERIENCE IN TEACHING FIRST YEAR STUDENTS: | | | | | | |
| 0 - 5 years | 8 | 28,6 | 4 | 18,2 | 12 | 24,0 |
| 6 - 10 years | 10 | 35,7 | 8 | 36,4 | 18 | 36,0 |
| 11 - 15 years | 4 | 14,3 | 4 | 18,2 | 8 | 16,0 |
| 16 - 20 years | 5 | 17,9 | 4 | 18,2 | 9 | 18,0 |
| 21 - 25 years | 1 | 3,6 | 1 | 4,5 | 2 | 4,0 |
| 26 - 30 years | 0 | 0,0 | 1 | 4,5 | 1 | 2,0 |
| 31 - 35 years | 0 | 0,0 | 0 | 0,0 | 0 | 0,0 |
| 3. FAMILIARITY WITH SCHOOL SYLLABUS: | | | | | | |
| Yes | 21 | 75,0 | 18 | 81,8 | 39 | 78,0 |
| No | 7 | 25,0 | 4 | 18,2 | 11 | 22,0 |
| 4. FAMILIARITY WITH SCHOOL EXAMINATIONS: | | | | | | |
| Yes | 11 | 39,3 | 10 | 45,5 | 21 | 42,0 |
| No | 17 | 60,7 | 12 | 54,5 | 29 | 58,0 |
| 5. FAMILIARITY WITH SCHOOL TEXT-BOOKS: | | | | | | |
| Yes | 17 | 60,7 | 11 | 50,0 | 28 | 56,0 |
| No | 11 | 39,3 | 11 | 50,0 | 22 | 44,0 |

TABLE 11.14 NATURE AND COMPOSITION OF THE SAMPLE OF LECTURERS WITH REFERENCE TO MEDIUM OF INSTRUCTION, EXPERIENCE, AND FAMILIARITY WITH PHYSICAL SCIENCE AT SCHOOL LEVEL

3.3.3 Of the 110 questionnaires sent to university lecturers 50 were returned, i.e. 45,5%. The data on the returns are summarised in TABLE 11.15 below.

| Total number of questionnaires | | Number of questionnaires returned | | | | | |
|--------------------------------|-----------|-----------------------------------|------|-----------|------|--------|------|
| | | PHYSICS | | CHEMISTRY | | TOTAL | |
| PHYSICS | CHEMISTRY | Number | % | Number | % | Number | % |
| 55 | 55 | 28 | 50,9 | 22 | 40,0 | 50 | 45,5 |
| 110 | | | | | | | |

TABLE 11.15 NUMBER AND PERCENTAGE OF QUESTIONNAIRES RETURNED BY UNIVERSITY LECTURERS

3.4 Observation of classroom practice

3.4.1 The observation schedule¹¹

The observation component of this study was carried out in 48 schools in the Cape Province as part of the author's normal visit as Inspector of Education for Sciences. For the purposes of this investigation a separate observation schedule, limited to methods of teaching, was completed for the teachers responsible for Physical Science in Standard 10 for each of the 48 schools. The classroom methods of these teachers were observed in Standard 8, Standard 9 and Standard 10 classes, where applicable.

The schedule was based on past observations as Inspector of Education of teaching methods used in high schools. On the basis of these observations the schedule was limited to four main methodological approaches, viz.

- (a) lecture methods;
- (b) discussion methods;
- (c) demonstration methods;
- (d) activity methods.

3.4.2 The size and nature of the sample

The sample of 48 schools represents 21,7% of the total population of 221. The representation of school types, setting and medium of instruction in the sample as compared to the population, is given in TABLE 11.16.

| | Sample (N = 48) | | Population (N = 221) | |
|---------------------------------|--------------------|------------|-------------------------|------------|
| | Number | Percentage | Number | Percentage |
| 1. SCHOOL TYPE | | | | |
| High | 44 | 91,7 | 206 | 93,2 |
| Agricultural | 2 | 4,2 | 5 | 2,3 |
| Technical | 2 | 4,2 | 10 | 4,5 |
| 2. SEX OF PUPILS | | | | |
| Boys | 7 | 14,6 | 29 | 13,1 |
| Girls | 5 | 10,4 | 17 | 7,7 |
| Co-educational | 36 | 75,0 | 175 | 79,2 |
| 3. MEDIUM OF INSTRUCTION | | | | |
| Afrikaans | 27 | 56,3 | 133 | 60,2 |
| English | 9 | 18,8 | 47 | 21,3 |
| Parallel | 12 | 25,0 | 41 | 18,6 |
| 4. LOCATION | | | | |
| Rural | 35 | 72,9 | 154 | 69,7 |
| Urban | 13 | 27,1 | 67 | 30,3 |

TABLE 11.16 SCHOOL TYPE, SCHOOL SETTING AND MEDIUM OF INSTRUCTION: REPRESENTATION IN THE SAMPLE

Although the sample was not specially selected but depended on an official inspection itinerary, the data in TABLE 11.16 show that it is reasonably representative of the population, especially regarding school type and the sex of the pupil population.

3.5 Analysis of examination papers

3.5.1 The final, external examination papers¹³

An external examination is written by candidates at the end of the three year course of study. Separate papers are set for Physical Science Higher Grade and Physical Science Standard Grade, and each paper tests the work of the last two years of the course (Standards 9 and 10).

A detailed analysis of all the papers set for the present course was not attempted. The purpose was only to select a suitable sample and to determine the types of knowledge assessed and whether the papers provided for assessment of the attainment of the stated syllabus aims.

3.5.2 The types of knowledge assessed

The following simplified classification was used for analysing the papers according to types of knowledge:¹⁴

1. Category A: Knowledge
Questions on the recall of information.
2. Category B: Comprehension
Questions in which principles have to be applied to situations which it is reasonable to expect candidates would have encountered in class or in textbooks, e.g. explanations of phenomena prescribed in the syllabus.
3. Category C: Application
Questions testing the ability to apply principles to situations which most pupils would not have encountered in class and where the pupils first have to select the appropriate principle.
4. Category D: Higher abilities
Questions on:
 - (a) The application of principles to problem situations, the solution of which would require two or more stages;

- (b) the design of experiments, including the selection of apparatus of suitable range, sensitivity and type;
- (c) the critical appraisal of measurements and the interpretation of data. Data supplied for simple problem-solving calculations are excluded since these operations belong to Categories B and C.

3.5.3 The assessment of the attainment of objectives

The official aims were listed and the percentage of the marks allocated to the testing of the attainment of these aims in each question, was entered opposite each aim and added to obtain the total percentages.

3.5.4 The selection of sample papers

The first differentiated examinations on the higher and standard grades in the Cape Province were conducted in November/December 1975. At that time both examiners and moderators were relatively inexperienced. It was thus decided to limit the analysis of examination papers to the papers of November 1976 and November 1977.

4. THE CRITERION BASED EVALUATION

The procedure outlined in Section 2.1.2 was used. The criteria were applied to official syllabuses and examinations only and not to commercially produced curriculum materials such as textbooks, laboratory manuals, teaching aids, data books and question books.¹⁵ The criteria for teaching-learning activities (methodological principles) were the only exceptions. These could not be applied to the large variety of teaching practices observed in the different schools, and special methods of teaching or methodological approaches are not prescribed by the Cape syllabuses.

15. See BIBLIOGRAPHY for a list of textbooks, laboratory manuals, question books and other published curriculum materials in use in South African schools.

CHAPTER 12THE SYLLABUS AIMS

1. SELECTION AND FORMULATION OF AIMS

1.1 Introductory

The aims of the teaching of Physical Science Higher Grade and Standard Grade are not stated explicitly but are included in the form of "general principles" in the "INTRODUCTION" to the two syllabuses. The introductions are identical for the two grades and each one consists of two sections, viz.

- (a) GENERAL, which contains the main statements on aims and objectives, and
- (b) NOTES, which, inter alia, contain information on practical work, including the aims of this component of the syllabuses.¹

The aims formulated below were extracted from this introduction. Wherever possible the formulations given below adhere as closely as possible to the original statements. The numbers in parentheses refer to the statements in the official syllabuses.

1.2 The official syllabus aims

1. To provide the pupil with a picture of Physical Science which reflects the status of the subject in our contemporary civilization and, in so doing,
2. to contribute to the development of useful and responsible citizens of this country (General: 1).
3. To provide those pupils who will continue their studies in this subject at university with a basis for further study and to supply the others with a rounded-off picture of Physical Science (General: 2).
4. To provide pupils with an understanding of the nature of physics and chemistry (Physical Science) as intellectual pursuits (sciences) (General: 3-a).

5. To provide pupils with an understanding of the application of the principles of physics and chemistry in technology (General: 3-b).
6. To provide the pupil with an understanding of the orderly framework of concepts, laws and theories upon which a science is structured (General: 4).
7. To provide the pupil with knowledge of those aspects of physics and chemistry which are of contemporary, everyday importance (General: 6).
8. To help pupils understand the fundamental role played by experimentation and observation in establishing and extending the body of scientific knowledge (Notes: 7.1).
9. To give pupils opportunities of making their own simple discoveries (Notes: 7.3).
10. To enable pupils to gain experience and practice in laboratory skills such as measuring techniques, recording and treatment of observations, representation of results, and the drawing of conclusions (Notes: 7.4 and 7.5).

For evaluation purposes these 10 aims were classified as follows:

1. Aims pertaining to the acquisition of knowledge (Aim 7).
2. Aims pertaining to physics and chemistry as disciplines (Aims 1, 4, 6 and 8).
3. Aims pertaining to the application of scientific principles in technology and industry (Aim 5).
4. Aims pertaining to laboratory procedures and skills (Aims 8, 9 and 10).
5. General educational aims such as citizenship and educationally functional knowledge, e.g. preparation for continued study (Aims 2 and 3).

Aims pertaining to

6. Attitudes, and
7. Interest

are not included in the official syllabuses but were also taken into consideration for evaluation purposes.

2. THE CRITERION-INDEPENDENT EVALUATION

2.1 Introductory

The syllabus aims were evaluated by means of questionnaires to teachers, university lecturers and pupils.² In this questionnaire teachers and lecturers were presented with 18 different aims and were requested to indicate whether a curriculum for Physical Science should provide for these various aims (a) directly, (b) indirectly, or (c) not at all. In addition, teachers were asked to rank 7 aims in order of decreasing importance. The questions to pupils were formulated in such a way as to obtain an indication of the realisation of the aims in practice.

2.2 Aims pertaining to the acquisition of knowledge

Two questions on the knowledge aspect were put to teachers and university lecturers, namely whether the aims for the teaching of Physical Science should provide for

1. aspects of knowledge of physics and chemistry which are of importance today (syllabus aim 7);
2. knowledge that is educationally functional (syllabus aims 2 and 3).

The data summarising the answers to these questions are given in TABLE 12.1.

| | AIM | | Specifically | Indirectly | Not at all |
|----|------------------------------------|-----------------------|----------------|----------------|-------------|
| 1. | Knowledge of physics and chemistry | Teachers (N = 171) | 91,8% (157) | 8,2% (14) | 0% (0) |
| | | Lecturers (N = 50) | 74,0 (37) | 22,0 (11) | 0 (0) |
| 2. | Educationally functional knowledge | Teachers (N = 171) | 18,7% (32) | 78,4% (134) | 2,9% (5) |
| | | Lecturers (N = 50) | 24,0 (12) | 50,0 (25) | 6,0 (3) |

TABLE 12.1 RESPONSES OF TEACHERS AND UNIVERSITY LECTURERS TO QUESTIONS ON AIMS PERTAINING TO THE ACQUISITION OF KNOWLEDGE

2.3 Aims pertaining to physics and chemistry as disciplines

Four questions pertaining to physics and chemistry as disciplines were included in the questionnaires to teachers and university lecturers. These were whether a legitimate aim of the teaching of physical science was -

1. to provide the pupil with a picture of the status of the subjects physics and chemistry in our contemporary civilization (syllabus aim 1);
2. to provide the pupil with an understanding of the nature of physics and chemistry as sciences (syllabus aim 4);
3. to provide the pupil with an understanding of the orderly framework of concepts, laws and theories upon which a science is structured (syllabus aim 6);
4. to provide the pupil with an understanding of the ways (methods) by which scientists work (scientific method) (syllabus aim 8).

The responses to these questions are summarised in TABLE 12.2.

| AIM | | Specifically | Indirectly | Not at all |
|--|-----------------------|---------------|----------------|-------------|
| 1. Picture of the status of the subjects | Teachers (N = 171) | 26,9% (46) | 67,8% (116) | 5,3% (9) |
| | Lecturers (N = 50) | 32,0 (16) | 60,0 (30) | 4,0 (2) |
| 2. Understanding of the nature of physics & chemistry as sciences | Teachers (N = 171) | 49,7% (85) | 47,7% (81) | 2,9% (5) |
| | Lecturers (N = 50) | 60,0 (30) | 36,0 (18) | 0 (0) |
| 3. Understanding of the orderly framework of concepts, laws and theories | Teachers (N = 171) | 56,7% (97) | 42,1% (72) | 1,2% (2) |
| | Lecturers (N = 50) | 66,0 (33) | 26,0 (13) | 0 (0) |
| 4. Understanding of the scientific method | Teachers (N = 171) | 46,2% (79) | 52,0% (89) | 1,8% (3) |
| | Lecturers (N = 50) | 60,0 (30) | 36,0 (18) | 0 (0) |

TABLE 12.2 RESPONSES OF TEACHERS AND UNIVERSITY LECTURERS TO QUESTIONS ON AIMS PERTAINING TO PHYSICS AND CHEMISTRY AS DISCIPLINES

2.4 Aims pertaining to the application of physics and chemistry in technology and industry

A single aim, viz. to provide pupils with an understanding of the application of scientific principles in technology and industry (syllabus aim 5), was included in the questionnaires. The responses to this question are summarised in TABLE 12.3.

| AIM | | Specifically | Indirectly | Not at all |
|---|-----------------------|----------------|---------------|------------|
| 1. Application of principles in technology and industry | Teachers (N = 171) | 66,1% (113) | 33,9% (58) | 0% (0) |
| | Lecturers (N = 50) | 40,0 (20) | 58,0 (29) | 2,0 (1) |

TABLE 12.3 RESPONSES OF TEACHERS AND UNIVERSITY LECTURERS TO A QUESTION ON AN AIM RELATED TO THE APPLICATION OF SCIENTIFIC PRINCIPLES IN TECHNOLOGY AND INDUSTRY

2.5 Aims pertaining to laboratory procedures and skills

Three aims included in the questionnaires related to laboratory experiences, viz.

1. to train pupils in the skills of using and handling scientific instruments and apparatus (syllabus aim 10);
2. to develop in pupils an enquiring approach to the solution of problems (syllabus aims 8 and 9);
3. to provide pupils with an understanding of scientific methods and procedures (syllabus aim 8).

The second of these aims also reflects a particular attitude while the third aim also refers to the nature of physics and chemistry as science disciplines. All three are, however, included in TABLE 12.4 for comparison in the context of laboratory-related aims.

| AIM | | Specifically | Indirectly | Not at all |
|--|-----------------------|----------------|---------------|-------------|
| 1. Training in laboratory skills | Teachers (N = 171) | 59,1% (101) | 39,2% (67) | 1,8% (3) |
| | Lecturers (N = 50) | 56,0 (28) | 38,0 (19) | 2,0 (1) |
| 2. Development of an enquiring approach | Teachers (N = 171) | 66,1% (113) | 33,9% (58) | 0% (0) |
| | Lecturers (N = 50) | 74,0 (37) | 22,0 (11) | 0 (0) |
| 3. Understanding of scientific method and procedures | Teachers (N = 171) | 46,2% (79) | 52,0% (89) | 1,8% (3) |
| | Lecturers (N = 50) | 60,0 (30) | 36,0 (18) | 0 (0) |

TABLE 12.4 RESPONSES OF TEACHERS AND UNIVERSITY LECTURERS TO QUESTIONS ON AIMS RELATED TO LABORATORY ACTIVITIES

2.6 General educational aims

The following aims are included under this heading:

1. To provide pupils with knowledge that is educationally functional;
2. to prepare pupils for life in a technological society (both indirectly related to syllabus aim 2);
3. to prepare pupils for continued study of the sciences or applied sciences (syllabus aim 3).

| AIM | | Specifically | Indirectly | Not at all |
|--|-----------------------|----------------|----------------|--------------|
| 1. Educationally functional knowledge | Teachers (N = 171) | 18,7% (32) | 78,4% (134) | 2,9% (5) |
| | Lecturers (N = 50) | 24,0 (12) | 50,0 (25) | 6,0 (3) |
| 2. Preparation for life in a technological society | Teachers (N = 171) | 26,3% (45) | 67,3% (115) | 6,4% (11) |
| | Lecturers (N = 50) | 32,0 (16) | 64,0 (32) | 0 (0) |
| 3. Preparation for continued study in the sciences or applied sciences | Teachers (N = 171) | 62,6% (107) | 35,7% (61) | 1,7% (3) |
| | Lecturers (N = 50) | 38,0 (19) | 56,0 (28) | 2,0 (1) |

TABLE 12.5 RESPONSES OF TEACHERS AND UNIVERSITY LECTURERS TO QUESTIONS ON GENERAL EDUCATIONAL AIMS

2.7 Aims pertaining to pupils' attitudes

Although aims directed at inculcating desirable attitudes or at changing or developing certain attitudes are not included as such in the syllabuses, questions on this aspect were included in order to obtain indications of the importance attached to attitudinal aims by teachers and university lecturers. The following aims were included in the questionnaires:

1. To develop an attitude of objectivity in pupils;
2. to develop an attitude of scientific honesty in pupils;
3. to lead pupils towards appreciation of and reverence for the wonders of nature and creation;

4. to make pupils aware of the power as well as the limitations of science.

Aims 1, 2 and 4 were selected to obtain an indication of their attainability through the prescribed syllabus content, while aim 3 was included because it is specifically mentioned in the syllabus for General Science³ which forms the foundation of Physical Science in the South African school system.

| AIM | | Specifically | Indirectly | Not at all |
|--|-----------------------|---------------|----------------|-------------|
| 1. Development of objectivity | Teachers (N = 171) | 39,8% (68) | 59,1% (101) | 1,2% (2) |
| | Lecturers (N = 50) | 56,0 (28) | 42,0 (21) | 0 (0) |
| 2. Development of scientific honesty | Teachers (N = 171) | 42,1% (72) | 53,2% (91) | 4,7% (8) |
| | Lecturers (N = 50) | 52,0 (26) | 44,0 (22) | 0 (0) |
| 3. Appreciation of and reverence for nature and creation | Teachers (N = 171) | 29,8% (51) | 67,3% (115) | 2,9% (5) |
| | Lecturers (N = 50) | 24,0 (12) | 60,0 (30) | 12,0 (6) |
| 4. Awareness of the power and limitations of science | Teachers (N = 171) | 21,1% (36) | 74,9% (128) | 4,1% (7) |
| | Lecturers (N = 50) | 14,0 (7) | 76,0 (38) | 2,0 (1) |

TABLE 12.6 RESPONSES OF TEACHERS AND UNIVERSITY LECTURERS TO QUESTIONS ON AIMS PERTAINING TO ATTITUDES

2.8 Aims pertaining to the development of interest

The development of pupils' interest in science, and activities and vocations of a scientific nature, is often stated as one of the aims of the teaching of science.⁴ To test the value placed by teachers and university lecturers on such an aim, one statement, of a fairly general nature, was included.

| AIM | | Specifically | Indirectly | Not at all |
|---|-----------------------|---------------|----------------|------------|
| 1. To arouse an interest in scientific vocations, literature and activities | Teachers (N = 171) | 38,6% (66) | 61,4% (105) | 0% (0) |
| | Lecturers (N = 50) | 36,0 (18) | 58,0 (29) | 0 (0) |

TABLE 12.7 RESPONSES OF TEACHERS AND UNIVERSITY LECTURERS TO A QUESTION ON AN AIM PERTAINING TO THE DEVELOPMENT OF INTEREST

2.9 The rank order of aims according to teachers

Seven aims were formulated for ranking in order from the most important to the least important according to the opinions of practising teachers. Five aims generally cited for the teaching of physics and chemistry⁵, formed the core of the list, viz.

1. the knowledge aim;
2. the skills aim;
3. scientific method as an aim;
4. the attitudes aim;
5. the interest aim.

To obtain an indication of the influence of the external examinations on the aims of teachers the following aim was added to the list:

6. To prepare pupils to pass a final examination.

A seventh aim, related to the official ultimate aim of education in this country, viz. Christian-National education, was also included:

7. To lead pupils towards an appreciation and reverence for the wonders of creation and nature.

The rank order obtained is detailed in TABLE 12.8.

| AIM | Rank | Rank index |
|--|------|------------|
| 1. To train pupils in <u>scientific methods</u> of work and ways of thinking | 1 | 2,59 |
| 2. To arouse in pupils an <u>interest</u> in natural phenomena, scientific vocations and literature, scientific hobbies, etc. | 2 | 3,65 |
| 3. To lead pupils towards an <u>appreciation of and reverence</u> for the wonders of creation | 3 | 3,86 |
| 4. To provide pupils with scientific <u>knowledge</u> | 4 | 3,92 |
| 5. To inculcate scientific <u>attitudes</u> and ideals (such as objectivity, honesty, application to a task, willingness to change views in the light of new evidence, etc.) | 5 | 4,34 |
| 6. To prepare pupils to pass a final <u>examination</u> | 6 | 4,49 |
| 7. To train pupils in the <u>skilful use of</u> scientific instruments and apparatus | 7 | 5,34 |

TABLE 12.8 TEACHERS' RANKING OF SEVEN GENERAL AIMS OF PHYSICS AND CHEMISTRY TEACHING

On the basis of this ranking one may conclude that teachers see their educational task as more important than their instructional task, emphasising scientific method, interest and appreciation and reverence, over knowledge, skills and attitudes. If, however, a similar rank order is compiled from the aims for which the curriculum should provide specifically, a different picture emerges (TABLE 12.9).

| AIM | Corresponding number(s) in questionnaire | Rank according to teachers | Rank according to lecturers |
|-------------------------|--|----------------------------|-----------------------------|
| 1. Scientific method | 5.9 | 4 (46,2%) | 3 (60,0%) |
| 2. Interest | 5.16 | 5 (38,6%) | 5 (36,0%) |
| 3. Wonder and reverence | 5.13 | 6 (29,8%) | 6 (24,0%) |
| 4. Knowledge | 5.1 | 1 (91,8%) | 1 (74,0%) |
| 5. Attitudes | 5.10 - 5.12 | 3 (50,5%) | 2 (60,6%) |
| 6. Examinations | No corresponding aim | - | - |
| 7. Skills | 5.15 | 2 (59,1%) | 4 (56,0%) |

TABLE 12.9 COMPARISON OF RANKS OF "IMPORTANCE OF AIMS", AND "AIMS FOR WHICH THE CURRICULUM SHOULD SPECIFICALLY PROVIDE"

According to teachers the curriculum should specifically provide for aims related to

1. knowledge;
2. skills;
3. attitudes.

These three aims are also reflected by the responses of the university lecturers, although they value attitudes more than skills. These three categories of aims are identical to those proposed by Frazer.⁶

2.10 The syllabus aims and practical teaching

Curriculum objectives as defined in Chapter 6, Section 2.2.2, should also serve to guide and direct the teacher in his planning, design of teaching-learning experiences and evaluation of the effectiveness of his teaching. The following questions on these aspects of the syllabus aims were put to teachers:

1. Are the aims comprehensive enough to relate to all aspects of the syllabus content?
2. Are the aims specific and explicit enough to provide the teacher with clear guidance as to what should be attained in each section of the syllabus?
3. Do you refer to the official aims when planning your work?
4. Does a perceptible relationship exist between the syllabus aims and the questions set in the Departmental examinations?

The teachers' responses to these questions are summarised in TABLE 12.10.

| QUESTION ON - | YES | NO |
|--|----------------|----------------|
| 1. Comprehensiveness of the aims | 73,7% (126) | 25,7% (44) |
| 2. Specificity and explicitness of the aims | 39,8% (68) | 60,2% (103) |
| 3. Use of aims in planning | 53,8% (92) | 43,3% (74) |
| 4. Existence of relationship between aims and examinations | 45,0% (77) | 55,0% (94) |

TABLE 12.10 TEACHERS' RESPONSES TO QUESTIONS ON THE NATURE AND USEFULNESS OF AIMS

2.11 The attainment of the syllabus aims according to pupils

With the exception of aims related to the acquisition of knowledge, the attainment of which can only be evaluated by means of attainment tests, the same classification of aims outlined in Section 1.2 will be followed:

1. Aims pertaining to physics and chemistry as disciplines

- (a) Did your study of Physical Science provide you with a clearer idea of the place and importance of physics and chemistry in the modern world? (Syllabus aim 1.)
- (b) Do you think that by studying Physical Science you have achieved a better understanding of the nature of Physics and Chemistry as sciences? (Syllabus aim 4.)
- (c) Did your study of Physical Science provide you with a clearer understanding of the orderly framework of concepts, theories and laws which form the basis of a science? (Syllabus aim 6.)
- (d) Did you obtain a clearer idea of the role of experimentation and observation as methods for obtaining scientific information? (Syllabus aim 8.)

2. Aims pertaining to application in technology and industry

- (a) Did you by studying Physical Science gain a better understanding of the application of scientific principles in technology and industry? (Syllabus aim 5.)

3. Aims pertaining to laboratory procedures and skills

- (a) Did you discover any scientific facts or principles yourself from doing practical work? (Syllabus aim 9.)
- (b) Did your study of Physical Science help you to become more proficient in the use of standard scientific apparatus and instruments? (Syllabus aim 10.)

4. General educational aims

- (a) Did you, by studying Physical Science, gain a better understanding of how physics and chemistry influence our daily lives? (Syllabus aims 1 and 7.)

- (b) Are you planning to follow a scientific course of study at a university?
 - (c) Are you planning any further scientific or technical studies at a college?
 - (d) Have you decided in favour of a post-matriculation course in the sciences or technology as a result of doing Physical Science at school? (Syllabus aim 3.)
 - (e) Have you decided against a post-matriculation course in the sciences or technology as a result of doing Physical Science at school? (Syllabus aim 3.)
 - (f) Do you think that Physical Science as a school subject will be of any value to you even though you may not continue your studies in a scientific field?
 - (g) Do you think that your education would have been poorer if you had not offered Physical Science as a school subject?
5. Aims pertaining to attitudes
- (a) Did your study of Physical Science give you a greater respect for and appreciation of the wonders of Nature and Creation?
6. Aims pertaining to interest
- (a) Are you interested in articles, lectures, talks, radio and television programmes, etc., about science?
 - (b) Do you subscribe to, or do you regularly read, scientific magazines?

The responses to these questions of the 1 219 pupils in the sample are summarised in TABLE 12.11.

| AIM | YES | NO | UNCERTAIN* |
|---|-----------------|---------------|----------------|
| 1.(a) Better understanding of roles of physics and chemistry | 83,9% (1023) | 7,9% (96) | 8,2% (100) |
| (b) Better understanding of nature of physics and chemistry | 78,7 (959) | 6,0 (73) | 15,3 (187) |
| (c) Better understanding of framework of concepts, theories, etc. | 81,3 (991) | 6,6 (81) | 12,1 (147) |
| (d) Better understanding of role of experimentation/observation | 79,8 (973) | 9,7 (118) | 10,5 (128) |
| 2.(a) Better understanding of application in technology/industry | 73,7 (898) | 16,4 (200) | 9,9 (121) |
| 3.(a) Self-discovery of scientific facts/principles | 25,4 (310) | 59,7 (728) | 14,8 (181) |
| (b) Proficiency in use of apparatus/instruments | 77,9 (949) | 14,0 (171) | 8,1 (99) |
| 4.(a) Better understanding of influence on daily lives | 80,0 (975) | 9,5 (116) | 10,5 (128) |
| (b) Intend following post-school university science course | 42,1 (513) | 47,1 (574) | 10,8 (132) |
| (c) Intend following post-school college science course | 11,7 (143) | 76,0 (927) | 12,2 (149) |
| (d) Decision for post-school course as result of study | 22,5 (274) | 62,7 (764) | 14,8 (181) |
| (e) Decision against post-school course as result of study | 11,2 (137) | 80,6 (982) | 8,2 (100) |
| (f) Physical Science of value for school leaver | 86,5 (1054) | 7,8 (95) | 5,7 (70) |
| (g) Education poorer without Physical Science | 73,4 (895) | 13,4 (163) | 13,2 (161) |
| 5.(a) Greater appreciation of and reverence for creation | 82,7 (1008) | 9,3 (113) | 8,0 (98) |
| 6.(a) Interest in talks, programmes, etc. in science | 72,4 (882) | 15,4 (188) | 12,2* (149) |
| (b) Reading of/subscription to science magazines | 43,6 (532) | 55,1 (672) | 1,2* (15) |

* Includes no response

TABLE 12.11 INDICATION OF ATTAINMENT OF AIMS ACCORDING TO PUPILS' RESPONSES (N = 1 219)

A rank order of the pupils' responses was compiled as follows:

1. Aims pertaining to physics and chemistry as disciplines: The averages of the raw scores of items 1(a), (b), (c) and (d) were used to calculate the percentage.
2. Aims pertaining to application in technology and industry: The actual percentage was used for this single item.
3. Aims pertaining to laboratory activities: The percentage was calculated on the average of the raw scores of items 3(a) and (b).
4. General educational aims: The percentage was calculated on the average of the raw scores of items 4(a), (f) and (g).
5. Aim pertaining to attitudes: The actual percentage was used for this single item.
6. Aims pertaining to interest: The percentage was calculated on the average of the raw scores of items 6(a) and (b).

The calculated percentages and ranking are summarised in TABLE 12.12.

| AIM | YES | NO | UNCERTAIN | RANK |
|----------------|-------|------|-----------|------|
| 1. Discipline | 80,9% | 7,5% | 11,5% | 2 |
| 2. Application | 73,7 | 9,7 | 10,5 | 4 |
| 3. Laboratory | 51,6 | 36,9 | 11,5 | 6 |
| 4. General | 80,0 | 10,2 | 9,8 | 3 |
| 5. Attitudes | 82,7 | 9,3 | 8,0 | 1 |
| 6. Interest | 58,3 | 35,3 | 6,7 | 5 |

TABLE 12.12 RANK ORDER OF ATTAINMENT OF CATEGORIES OF AIMS ACCORDING TO PUPILS (N = 1 219)

The fairly high percentages recorded for the "YES" responses (TABLE 12.11) should be interpreted with care. Most of the questions require answers to phrases like: "Did your study of Physical Science provide you with a better understanding of ...". The actual depth of understanding could not be ascertained by means of a questionnaire of this nature. It is therefore to be expected that pupils would answer in the affirmative after three years' exposure to the study of Physical Science. Interpretation of the results will, therefore, be based on the rank order rather than on the actual scores.

2.12 Evaluation of the syllabus aims

2.12.1 The representativeness of the aims

The official syllabus aims are distributed among the different categories as follows:

1. Knowledge:

The syllabuses provide for one aim in this category only (syllabus aim 7).

2. Physics and chemistry as disciplines:

Four syllabus aims belong to this category (aims 1, 4, 6 and 8).

3. Application in technology and industry:

The syllabuses provide for one aim in this category (syllabus aim 5).

4. Laboratory procedures and skills:

Three aims (syllabus aims 8, 9 and 10), may be related to this category.

5. General educational aims:

Two aims (syllabus aims 2 and 3), belong to this group.

6. Attitudes:

No aims of this type are included.

7. Interest:

No aims are included.

The following conclusions and inferences may be drawn:

1. No distinction is made between the aims for Physical Science Higher Grade and Physical Science Standard Grade. This lack of differentiation indicates that both courses are intended to serve the same purposes, but for pupils of different abilities.
2. There is an imbalance among the syllabus aims as is evident from the four aims related to the disciplinary nature of physics and chemistry and the lack of aims pertaining to attitudes and interest.
3. The emphasis on the nature of chemistry and physics as disciplines indicates that the syllabuses are of a formal and academic nature and it is likely that the teaching aims may be influenced by this.

2.12.2 The range of the syllabus aims

The official syllabus aims were compared to the specific aims selected by teachers and university lecturers. Although the rank order correlation between the choices of teachers and lecturers is high (0,80), the combination of the responses of the 171 teachers and 50 lecturers on the basis of the raw scores may be weighted towards the teachers' opinions, whereas a combination of the percentages may favour the opinions of the lecturers. The following table (TABLE 12.13) supplies the results obtained by using both methods of combination.

| AIM | Combined responses based on RAW SCORES | RANK | Combined responses based on PERCENTAGES | RANK |
|------|--|------|---|------|
| 5.1 | 87,8% | 1 | 82,9% | 1 |
| 5.2 | 19,9 | 15 | 21,4 | 15 |
| 5.3 | 28,1 | 13 | 29,5 | 12 |
| 5.4 | 52,0 | 7 | 54,9 | 5 |
| 5.5 | 60,2 | 3 | 53,1 | 6,5 |
| 5.6 | 57,0 | 6 | 50,3 | 8 |
| 5.7 | 27,6 | 14 | 29,2 | 13 |
| 5.8 | 58,8 | 4 | 61,4 | 3 |
| 5.9 | 49,3 | 8 | 53,1 | 6,5 |
| 5.10 | 67,9 | 2 | 70,1 | 2 |
| 5.11 | 43,4 | 10 | 47,9 | 9 |
| 5.12 | 44,3 | 9 | 47,1 | 10 |
| 5.13 | 28,5 | 12 | 26,9 | 14 |
| 5.14 | 19,5 | 16 | 17,6 | 16 |
| 5.15 | 58,4 | 5 | 57,6 | 4 |
| 5.16 | 38,0 | 11 | 37,3 | 11 |

TABLE 12.13 COMPARISON OF TWO METHODS OF COMBINING TEACHERS' AND LECTURERS' SELECTION OF SPECIFIC AIMS

The rank order correlation between these two methods is very high (0,95) and either one may be used as the basis of selection provided that any large differences in rank order are taken into account. Such differences occur in the responses to aims 5.5 and 5.6 which differ by 6,5 and 6 respectively.

On the basis of the combined responses of teachers and lecturers syllabus aims should provide specifically for the following:

1. Knowledge;
2. development of an enquiring approach to problem solving;
3. understanding of the orderly framework of concepts, laws and theories upon which a science is structured;
4. skill in the use and handling of scientific apparatus and instruments;
5. application of scientific principles in technology and industry;
6. preparation for continued study in the sciences or applied sciences;
7. understanding of the nature of physics and chemistry as sciences;
8. understanding of the ways by which scientists work (scientific method).

All these aims are provided for directly in the official syllabus aims (3, 4, 5, 6, 7, 8 and 10). The syllabus aims thus comply with the requirements according to teachers and university lecturers.

Neither teachers nor lecturers see the need to provide specifically for aims pertaining to attitudes and interest. The fact that these categories of aims are considered to be important according to teachers' ranking of seven selected aims (TABLE 12.8) seems to be in complete contradiction to their low frequency of selection as specific aims.

2.12.3 The syllabus aims as practical guides for teaching

According to TABLE 12.10 the syllabus aims are sufficiently comprehensive to relate to all aspects of the syllabus content. This result is to be expected since the aims are stated in very general terms.

The majority of teachers (60,2%) do not find the aims specific and explicit enough to provide them with clear guidance on what should be attained with each section of the syllabus, and 55% cannot see any relationship between the official aims and the nature and content of the questions set in the final, external examinations. It is thus not surprising that only some 53,8% of the teachers state that they refer to the aims in planning their teaching.

One may thus conclude that the aims are

1. sufficiently comprehensive;
2. not specific enough to provide guidance on what is intended by each section or unit of the syllabus;
3. unsatisfactory as aids in planning the teaching;
4. unsatisfactory as aids and guides to evaluation.

2.12.4 Attainment and attainability of the aims

According to Standard 10 pupils the following aims are most successfully attained in schools (in the given order):

1. Aims pertaining to attitudes (reverence for the wonders of creation and nature);
2. aims pertaining to the disciplinary nature of physics and chemistry;
3. general educational aims (influence of science on our daily lives; educational value of Physical Science).

The following aims are less successfully attained:

4. understanding of the application of scientific principles in technology and industry;
5. development of interest in science-based literature, vocations, hobbies, etc.;
6. aims pertaining to laboratory activities.

This rank order indicates that the syllabus content may not include enough examples or material related to the application of principles in technology and industry, that the topics themselves may be uninteresting or so difficult or abstract that they have a negative effect on the development of scientific interests in pupils, and either that the prescribed laboratory experiences are insufficient, or that practical work does not receive the required attention in the teaching methods employed.

Whatever the reasons may be, the attainability of aims is intimately related to both content and method. At this stage one may tentatively conclude that the syllabus content apparently does not provide sufficiently for the attainment of the aims pertaining to application, interest and laboratory activities.

2.12.5 Summary

The conclusions based on this part of the evaluation may be summarised as follows:

1. Lack of differentiation between the aims for the Higher and Standard Grade courses.
2. Imbalance among the different categories of aims.
3. Overemphasis of the formal and academic aspects of the subject.
4. The official aims comply with the requirements according to teachers and university lecturers.
5. The aims are comprehensive enough to relate to all aspects of the syllabus content.
6. The aims are not specific enough to provide clear guidance on all aspects of the syllabus content.
7. The aims are unsatisfactory as guides to planning teaching.
8. The aims are unsatisfactory as guides to evaluation.
9. Aims pertaining to application, interest and laboratory activities may not be sufficiently provided for in the syllabus content and teaching method.

3. THE CRITERION-BASED EVALUATION

3.1 Introductory

The criteria for curriculum objectives were applied to the ten syllabus aims (Section 1.2) in order to determine their value and acceptability in the context of the curriculum model.

3.2 The criterion of convergence

- 3.2.1 According to this criterion curriculum objectives should converge into a single focus, viz. the ultimate aim of education. In the case of the syllabuses for Physical Science no such ultimate aim is formulated.

The National Education Act⁷, however, states that the education should have a Christian-National character. It is reasonable to expect that the aims for all the school subjects offered in government schools should be directed at the attainment of this official goal. The criterion of convergence will thus be applied to this ultimate aim.

- (a) The Christian Ideal: No syllabus aim contains any reference to, or contributes to, the ultimate aim of a Christian education. (The aim "to lead pupils towards appreciation of and reverence for the wonders of creation and nature", which is included in the questionnaires, is derived from the syllabus for General Science and not Physical Science.)
- (b) The National Aim: One aim - "to contribute to the development of useful and responsible citizens of this country" - can be said to be directly related to the national aim of education. According to the introduction to the syllabuses this is to be achieved through providing pupils with a picture of Physical Science which reflects the status of the subject in our contemporary civilization. Both these statements of aim are phrased in vague and general terms.

One would expect that syllabus aim 5 (application of scientific principles in technology) would specify technologies and industries of national character and importance, e.g. minerals and mining, the petrochemical industry based on coal, etc. Similar remarks apply to syllabus aim 7 (knowledge of aspects which are of contemporary, everyday importance).

It may thus be concluded that the syllabus aims do not contribute effectively to the attainment of the official aim of education in South Africa.

- 3.2.2 The second aspect of the criterion of convergence is that of "internal supportiveness". The classification of the syllabus aims (see Section 1.2) reveals that they are internally supportive in the context of convergence towards a formal study of physics and chemistry as intellectual pursuits (disciplines). Four aims are directly related to this aspect, and two out of three aims pertaining to laboratory experiences are directed at scientific methods of investigation.

This conclusion is further strengthened by the complete lack of aims related to attitudes and interest. The syllabus aims are not internally supportive in their relation to the general aim of education but they are strongly supportive in the context of a formal study of physics and chemistry as scientific disciplines.

3.2.3 The final aspect of the criterion of convergence is that the aims should be non-contradictory. Two possible contradictions are immediately apparent, viz.

- (a) the identical nature of the aims for the Higher Grade and Standard Grade syllabuses, and
- (b) the statement in syllabus aim 3 that provision should be made for both continued study in the sciences and for a rounded-off picture of Physical Science for those pupils who do not intend continuing their studies in the sciences.

3.3 The criterion of validity

Curriculum objectives should be valid in the educational, societal, professional and vocational contexts.

- (a) Educational: The validity of aims directed at a formal academic study of physics and chemistry at school level for a Standard Grade course must be seriously questioned on educational grounds. The fact that such a large proportion of pupils (71,7% of the candidates for the final examination) offers the subject on the Higher Grade, introduces a large measure of uncertainty about the validity of these aims for this grade as well.

Uncertainty about the validity of aims formulated for laboratory activities, and in particular for discovery methods (syllabus aims 8 and 9), have already been discussed in Chapter 6, Section 3.5.2.

- (b) Societal: With the exception of one school for Chinese pupils, the Cape syllabuses are followed in schools for white pupils. Of the 221 schools offering Physical Science as a subject 67 (30,3%) are situated in urban areas and 154 (69,7%) in rural areas. They represent 45,4% and 54,6% of the pupils respectively.

The syllabus aims seem to be "neutral" in the societal context. No special provision is made for the needs and interests of the two groups of pupils, and the social implications of science are not mentioned at all.

- (c) Vocational: It is often said that the aims of the syllabuses for Physical Science, and the course itself, are directed at the small minority of pupils who intend continuing their studies in the sciences and related areas at university.⁸ Although a small percentage of the total school population proceeds to tertiary studies, the percentage of pupils offering Physical Science at school who intend enrolling at universities, is remarkably high. According to the questionnaire to pupils⁹ 42,1% of the sample intends following a tertiary course of study in the pure and applied sciences. The estimated percentage of actual enrolments for all university science courses (B.Sc., medicine, dentistry, veterinary science, engineering, agricultural sciences, domestic science, computer science, etc.) based on the total number of white candidates offering Physical Science Higher Grade and Standard Grade, is of the order of 30%.¹⁰ This is definitely not a small minority.

The syllabus aim "to provide pupils with a basis for further study" is thus a valid one in the vocational context, although it may be questioned whether this should apply to the Standard Grade as well.

In view of the present needs of the country for technicians in a variety of science-related fields, the limitation of the aim to study at a university¹¹ and the over-emphasis of aims related to the academic study of physics and chemistry, cast serious doubt on the validity of the syllabus aims in the vocational context for all pupils but those intending to proceed to a university.

3.4 The criterion of appropriateness

Curriculum objectives should be appropriate to the age, maturity, readiness, ability, existing knowledge and understanding of the pupils, and to their social, cultural and economic backgrounds.

The first component of this criterion refers mainly to appropriateness to the psychological readiness of the learner. If it is considered that the three-year course in Physical Science provides for the age range 15+ to 17+ years, and that the same aims apply to all three years of the course, it is obvious that the emphasis on the disciplinary nature of physics and chemistry and the academic study of these subjects suggests that the majority of syllabus aims are not appropriate to the age, maturity, readiness and understanding of the pupils concerned. The type of study indicated by the aims "demands a particular level of concept development".¹²

In the light of the discussion in Section 3.3(b) the aims may be said to be appropriate to the social, cultural and economic backgrounds of only a small fraction of the pupils concerned, i.e. mainly those from professional homes.

3.5 The criterion of precision

All the syllabus aims are stated in broad and general terms, perhaps with the single exception of aim 9, namely to provide pupils with opportunities of making their own simple discoveries. The aims do not supply the teacher and pupil with clear direction and guidance regarding the interpretation of the content, the knowledge, skills and attitudes required and the evaluation of the content.

3.6 The criterion of comprehensiveness

According to this criterion the aims should provide for as large a range of abilities, interests and values as is possible within the limitations imposed by the pupil population, the nature of the subject and practical feasibility. Although the syllabus aims are very general, they tend to focus on an academic-disciplinary approach, disregarding the various values which may be related to science teaching as well as the different abilities and interests of the pupil population.

3.10 Summary

The syllabus aims do not comply with the criteria for curriculum objectives in respect of

- (a) convergence;
- (b) validity in the educational and societal contexts;
- (c) precision;
- (d) comprehensiveness;
- (e) relevance.

They comply partially, or to certain groups of pupils only, with the criteria of

- (a) validity in the vocational context;
- (b) appropriateness;
- (c) realism.

The syllabus aims, because of their general and unspecified nature, comply with the criterion of

- (a) flexibility.

4. COMPARISON OF THE RESULTS OF THE TWO EVALUATIONS

4.1 It is doubtful whether a valid comparison can be made of the results of two such completely different approaches to curriculum evaluation, especially since the questionnaires were designed independently of the criteria at a stage of the investigation when the need for the formulation of criteria was not yet foreseen (see Chapter 1). The comparison must thus be limited to general conclusions and to obviously similar or obviously contradictory findings.

4.2 The criteria of convergence, appropriateness and flexibility have no comparable counterparts in the criterion-independent evaluation.

The following findings seem to be in full agreement:

| | |
|--|---|
| 1. (a) <u>Lack of differentiation</u> (b) <u>Imbalance</u> (c) <u>Over-emphasis of formal and academic aspects</u> | <u>Invalid</u> in educational and societal contexts |
| 2. (a) <u>Not specific</u> (b) <u>Unsatisfactory guides to planning</u> (c) <u>Unsatisfactory guides to evaluation</u> | <u>Lack of precision</u> |
| 3. <u>Aims pertaining to application, interest and laboratory activities not sufficiently provided for</u> | <u>Lack of relevance</u> |

The following result seems to be contradictory: According to teachers the aims are sufficiently comprehensive, whereas application of the criterion of comprehensiveness reveals the opposite. It should be kept in mind, however, that the teachers' opinions refer to "comprehensive enough to relate to all aspects of the syllabus content" whereas the criterion refers to the range of objectives.

Attainability (which relates to the criterion of realism) was judged on the basis of the pupils' responses. According to pupils, attainment is least successful in the areas of application, interest and laboratory activities (TABLE 12.12). At this stage no final conclusion can be arrived at as to whether this trend is due to the unrealistic nature of the aims, the teaching methods employed, the selected content, other factors, or combinations of these.

In general it may be concluded that both evaluations reveal major weaknesses and shortcomings in the syllabus aims. Both agree particularly well in isolating the lack of validity, precision and relevance.

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2. See APPENDICES III, IV and V.
3. Provincial Administration of the Cape of Good Hope: Department of Education, Junior Secondary Course: Syllabus for General Science. (Cape Town: Department of Education, Cape of Good Hope, 1973). p. 2.
4. M.J. Frazer, "Up-to-date and precise learning objectives in chemistry", E. Cartmell (ed.), New Trends in Chemistry Teaching IV. (Paris: The Unesco Press, 1975), p. 46.
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6. Ibid., p. 48. (Also see Chapter 6, Section 2.2.4).
7. Government Gazette, Government Notice No. R.2029: National Education Policy Act 1967 - Education in Schools. (Pretoria: The Government Printer, November 1971).
8. Die Burger (Newspaper article). (Cape Town, 25 April 1975).
9. APPENDIX IV, question 13. (Also see TABLE 12.11.)
10. Information supplied by Secretary, Committee of University Principals, Letter, dated 8 August 1978.
11. Provincial Administration of the Cape of Good Hope, Department of Education, Senior Secondary Course: Syllabus for Physical Science (Higher Grade), op. cit., p. 2.
12. David Cohen, "New approaches to the design and evaluation of chemistry courses", Cartmell (ed.), op. cit. (ref. 4), p. 92.

CHAPTER 13THE SYLLABUS CONTENT

1. OUTLINE OF THE SYLLABUS STRUCTURE

1.1 The Higher Grade and Standard Grade syllabuses

The two syllabuses,¹ one for the Higher Grade and one for the Standard Grade, contain basically the same material. Some topics, or parts of topics, and certain experiments are simply excluded from the Higher Grade syllabus to make up the Standard Grade syllabus. The original syllabuses were slightly reduced in 1976.²

Each syllabus is divided into three parts. Part I, covering the work of the first year of the course (Standard 8) contains physics and chemistry; Part II, which contains the content for the second year of the course, consists mainly of physics and the electronic structure of the atom; Part III, covering the final year of the course, consists entirely of chemistry.³ The final, external examinations, which are taken at the end of the course, are set on the work of the second and third years (Standards 9 and 10). Separate examinations are set for the Higher and Standard Grade. A minimum score of $33\frac{1}{3}\%$ is required to pass on the Standard Grade and 40% to pass on the Higher Grade.

1.2 The syllabus topics

Details of the syllabuses are supplied in APPENDIX VI. The topics included in the syllabuses are the following:

(a) Standard 8 (First year)

1. Light.
2. Sound.
3. Heat, work and internal energy.
4. Electricity.
5. Atomic structure.

6. Chemical reactions of metals and non-metals.
7. Acids, bases and salts.
8. Chemical reactions and electricity.
9. Reactions involving ions.

(b) Standard 9 (Second year)

1. Vectors.
2. Displacement-time and velocity-time relationships.
3. Bodies in motion.
4. Electrostatics.
5. The electric current.
6. Thermionic emission.
7. Light.
8. Electromagnetic waves and light.
9. Particles, waves and quanta.
10. The atomic nucleus.
11. Atomic structure.

(c) Standard 10 (Third year)

1. Chemical bonding.
2. Three phases of matter.
3. Solutions.
4. Rates of chemical reactions.
5. Equilibrium in chemical reactions.
6. Electrochemical cells.
7. Oxidation-reduction.
8. Organic chemistry.

From this list, which may be used as an aid in interpreting the answers to the questionnaires, it is obvious that the chemistry content consists mainly of physical chemistry.

2. THE CRITERION-INDEPENDENT EVALUATION

2.1 Introductory

An identical questionnaire was completed by teachers and university lecturers. The questionnaire contained a list of 24 units, each subdivided into a number of smaller topics, based on the official syllabuses. A limited number of topics from overseas curricula

were added to the appropriate units. In addition to the questionnaire teachers and lecturers were also supplied with an appendix to the questionnaire in which each topic was further detailed.

Respondents were requested to indicate which topics they considered ESSENTIAL, which DESIRABLE, and which UNNECESSARY for inclusion in a curriculum for Physical Science. In addition they were asked to indicate those topics which, in their opinion, could be taught at an earlier age, i.e. before Standard 8. This aspect of the questionnaire eventually had to be rejected as a result of the limited response.

2.2 General topics

A unit on "Scientific procedures", which does not appear in the official syllabuses, was included in the questionnaire. The content of this unit was based mainly on the corresponding section of the CHEM Study Course.⁴

In the following, and subsequent tables, teachers' responses are indicated by the letter T and those of university lecturers by the letter L.

| CONTENT | | Essential | Desirable | Unneces- sary |
|--|------------|---------------|---------------|------------------|
| 1. <u>Scientific procedures</u> | | | | |
| 1.1 Scientific methods of work | T (171) | 46,2% (79) | 50,3% (86) | 1,8% (3) |
| | L (46) | 60,9 (28) | 30,4 (14) | 6,5 (3) |
| 1.2 Uncertainty and validity of measure- ments | T (171) | 14,0 (24) | 71,9 (123) | 14,0 (24) |
| | L (46) | 34,8 (16) | 60,9 (28) | 4,3 (2) |
| 1.3 Scientific communi- cation | T (171) | 22,2 (38) | 69,0 (118) | 7,0 (12) |
| | L (46) | 32,6 (15) | 52,2 (24) | 10,9 (5) |

TABLE 13.1 RESPONSES OF TEACHERS AND UNIVERSITY LECTURERS TO QUESTIONS ON CONTENT: SCIENTIFIC PROCEDURES

2.3 The physics content - mechanics

The three units included in this section are

2. Vectors
3. Displacement-time and velocity-time relationships.
4. Bodies in motion.

(The numbers refer to the numbering in the questionnaire.)

| CONTENT | | Essential | Desirable | Unneces- sary |
|---|------------|----------------|---------------|------------------|
| 2.1 Displacement | T (171) | 78,9% (135) | 19,9% (34) | 0% (0) |
| | L (28) | 82,1 (23) | 10,7 (3) | 3,6 (1) |
| 2.2 Displacement and force as examples of vectors | T (171) | 77,2 (132) | 21,0 (36) | 0 (0) |
| | L (28) | 82,1 (23) | 10,7 (3) | 3,6 (1) |
| 2.3 Equilibrium of forces | T (171) | 77,2 (132) | 19,9 (34) | 1,8 (3) |
| | L (28) | 78,6 (22) | 7,1 (2) | 10,7 (3) |
| 2.4 Components | T (171) | 80,1 (137) | 18,7 (32) | 0 (0) |
| | L (28) | 82,1 (23) | 3,6 (1) | 10,7 (3) |
| 2.5 Velocity and acceleration | T (171) | 81,3 (139) | 18,1 (31) | 0 (0) |
| | L (28) | 82,1 (23) | 10,7 (3) | 3,6 (1) |
| 3.1 Graphic representations | T (171) | 55,0 (94) | 39,8 (68) | 4,1 (7) |
| | L (28) | 89,3 (25) | 7,1 (2) | 0 (0) |
| 3.2 Experimental investigation | T (171) | 52,0 (89) | 39,8 (68) | 7,0 (12) |
| | L (28) | 60,7 (17) | 35,7 (10) | 3,6 (1) |

| CONTENT | | Essential | Desirable | Unneces- sary |
|---|------------|----------------|---------------|------------------|
| 3.3 Equations of motion | T (171) | 80,1% (137) | 18,7% (32) | 0% (0) |
| | L (28) | 64,3 (18) | 35,7 (10) | 0 (0) |
| 4.1 Newton's First Law | T (171) | 87,1 (149) | 12,3 (21) | 0 (0) |
| | L (28) | 92,9 (26) | 7,1 (2) | 0 (0) |
| 4.2 Newton's Second Law | T (171) | 87,7 (150) | 11,1 (19) | 0 (0) |
| | L (28) | 92,9 (26) | 7,1 (2) | 0 (0) |
| 4.3 Circular motion | T (171) | 15,8 (27) | 46,8 (80) | 36,3 (62) |
| | L (28) | 17,9 (5) | 60,7 (17) | 21,4 (6) |
| 4.4 Newton's law of universal gravita- tion | T (171) | 67,8 (116) | 29,2 (41) | 1,8 (3) |
| | L (28) | 60,7 (17) | 32,1 (9) | 7,1 (2) |
| 4.5 Newton's Third Law | T (171) | 67,8 (116) | 24,0 (41) | 7,0 (12) |
| | L (28) | 78,6 (22) | 14,3 (4) | 7,1 (2) |
| 4.6 Momentum | T (171) | 86,0 (147) | 12,9 (22) | 0 (0) |
| | L (28) | 67,9 (19) | 25,0 (7) | 7,1 (2) |
| 4.7 Work, energy and power | T (171) | 86,0 (147) | 12,3 (21) | 0,6 (1) |
| | L (28) | 92,9 (26) | 7,1 (2) | 0 (0) |

TABLE 13.2 RESPONSES OF TEACHERS AND UNIVERSITY LECTURERS TO QUESTIONS ON CONTENT: MECHANICS

2.4 The physics content - electricity

The three units comprising this section are

5. Electrostatics.
6. The electric current.
7. Electronics.

| CONTENT | | Essential | Desirable | Unneces- sary |
|---|------------|---------------|----------------|------------------|
| 5.1 Revision of qualitative study of electrostatics (General Science) | T (171) | 21,6% (37) | 59,1% (101) | 19,3% (33) |
| | L (28) | 71,4 (20) | 25,0 (7) | 0 (0) |
| 5.2 Force between charges: Coulomb's Law | T (171) | 60,8 (104) | 33,3 (57) | 5,8 (10) |
| | L (28) | 89,3 (25) | 7,1 (2) | 3,6 (1) |
| 5.3 Electric fields | T (171) | 66,1 (113) | 29,8 (51) | 4,1 (7) |
| | L (28) | 85,9 (24) | 7,1 (2) | 7,1 (2) |
| 5.4 Quantisation of charge: Millikan's experiment | T (171) | 50,3 (86) | 39,8 (68) | 9,9 (17) |
| | L (28) | 35,7 (10) | 53,6 (15) | 10,7 (3) |
| 6.1.1 Current; the ampere | T (171) | 86,5 (148) | 13,5 (23) | 0 (0) |
| | L (28) | 100 (28) | 0 (0) | 0 (0) |
| 6.1.2 Potential difference; the volt | T (171) | 88,9 (152) | 11,1 (19) | 0 (0) |
| | L (28) | 100 (28) | 0 (0) | 0 (0) |
| 6.1.3 Resistance; the ohm | T (171) | 87,7 (150) | 12,3 (21) | 0 (0) |
| | L (28) | 100 (28) | 0 (0) | 0 (0) |
| 6.1.4 Emf and internal resistance | T (171) | 62,6 (107) | 31,6 (54) | 5,8 (10) |
| | L (28) | 92,9 (26) | 7,1 (2) | 0 (0) |

| CONTENT | | Essential | Desirable | Unneces- sary |
|--|------------|----------------|---------------|------------------|
| 6.2.1 Effect of rise in temperature | T (171) | 63,7% (109) | 34,5% (59) | 1,8% (3) |
| | L (28) | 75,0 (21) | 17,9 (5) | 7,1 (2) |
| 6.2.2 Magnetic effects | T (171) | 71,9 (123) | 28,1 (48) | 0 (0) |
| | L (28) | 85,7 (24) | 10,7 (3) | 3,6 (1) |
| 6.2.3 Electromagnetic induction | T (171) | 67,3 (115) | 31,6 (54) | 1,2 (2) |
| | L (28) | 71,4 (20) | 25,0 (7) | 3,6 (1) |
| 6.3 Electric current as a flow of charge | T (171) | 75,4 (129) | 21,6 (37) | 0,6 (1) |
| | L (28) | 92,9 (26) | 7,1 (2) | 0 (0) |
| 6.4 Force on current-bearing conductors | T (171) | 56,1 (96) | 33,9 (58) | 8,8 (15) |
| | L (28) | 60,7 (17) | 35,7 (10) | 3,6 (1) |
| 6.5 Magnetic field and field strength | T (171) | 49,1 (84) | 36,8 (63) | 14,0 (24) |
| | L (28) | 64,3 (18) | 28,6 (8) | 7,1 (2) |
| 6.6 Ohm's Law | T (171) | 81,3 (139) | 18,1 (31) | 0 (0) |
| | L (28) | 92,9 (26) | 3,6 (1) | 3,6 (1) |
| 6.7 Heating effect (quantitative) | T (171) | 36,3 (62) | 44,4 (76) | 18,1 (31) |
| | L (28) | 75,0 (21) | 25,0 (7) | 0 (0) |
| 6.8 Alternating current | T (171) | 57,3 (98) | 41,5 (71) | 0,6 (1) |
| | L (28) | 21,4 (6) | 64,3 (18) | 14,3 (4) |

| CONTENT | | Essential | Desirable | Unneces- sary |
|---|------------|----------------|---------------|------------------|
| 7.1 Thermionic emission | T (171) | 63,2% (108) | 31,0% (53) | 5,3% (9) |
| | L (28) | 21,4 (6) | 28,6 (8) | 50,0 (14) |
| 7.2 Thermionic diode and its applications | T (171) | 49,1 (84) | 39,2 (67) | 11,1 (19) |
| | L (28) | 10,7 (3) | 25,0 (7) | 64,3 (18) |
| 7.3 Vacuum triode and its applications | T (171) | 18,1 (31) | 37,4 (64) | 42,4 (73) |
| | L (28) | 7,1 (2) | 21,4 (6) | 71,4 (20) |
| 7.4 Transistor | T (171) | 28,1 (48) | 36,8 (63) | 32,7 (56) |
| | L (28) | 17,9 (5) | 50,0 (14) | 32,1 (9) |
| 7.5 Reception and modulation of radio waves | T (171) | 14,0 (24) | 46,2 (79) | 38,0 (65) |
| | L (28) | 7,1 (2) | 50,0 (14) | 42,9 (12) |

TABLE 13.3 RESPONSES OF TEACHERS AND UNIVERSITY LECTURERS TO QUESTIONS ON CONTENT: ELECTRICITY

2.5 The physics content - waves and wave-phenomena

Four units are included in this section, viz.

8. Waves.
9. Sound.
10. Light.
11. Particles, waves and quanta.

| CONTENT | | Essential | Desirable | Unneces- sary |
|---|------------|---------------|---------------|------------------|
| 8.1 Vibration as intro- duction to periodic motion; terminology | T (171) | 46,8% (80) | 47,4% (81) | 0,6% (1) |
| | L (28) | 89,3 (25) | 10,7 (3) | 0 (0) |
| 8.2 Graphic represen- tation of a disturbance versus time | T (171) | 46,2 (79) | 45,6 (78) | 7,0 (12) |
| | L (28) | 82,1 (23) | 17,9 (5) | 0 (0) |
| 8.3 Polarisation, extinction and superposition | T (171) | 64,9 (111) | 32,2 (55) | 2,9 (5) |
| | L (28) | 46,4 (13) | 32,1 (9) | 17,9 (5) |
| 8.4 Energy transfor- mations | T (171) | 48,5 (83) | 42,1 (72) | 8,2 (14) |
| | L (28) | 28,6 (8) | 42,9 (12) | 25,0 (7) |
| 8.5 Interference and diffraction | T (171) | 69,6 (119) | 24,0 (41) | 5,8 (10) |
| | L (28) | 42,9 (12) | 35,7 (10) | 17,9 (5) |
| 8.6 Standing waves | T (171) | 36,3 (62) | 43,3 (74) | 19,9 (34) |
| | L (28) | 53,6 (15) | 39,3 (11) | 7,1 (2) |
| 9.1 Production of sound | T (171) | 26,9 (46) | 60,8 (104) | 9,9 (17) |
| | L (27) | 51,9 (14) | 40,7 (11) | 7,4 (2) |

| CONTENT | | Essential | Desirable | Unneces- sary |
|--|------------|---------------|----------------|------------------|
| 9.2 Transmission of sound | T (171) | 26,9% (46) | 62,0% (106) | 8,8% (15) |
| | L (27) | 59,3 (16) | 29,6 (8) | 11,1 (3) |
| 9.3.1 Speed of sound | T (171) | 25,7 (44) | 62,6 (107) | 9,9 (17) |
| | L (27) | 59,3 (16) | 33,3 (9) | 7,4 (2) |
| 9.3.2 Reflection of sound | T (171) | 22,8 (39) | 63,7 (109) | 12,3 (21) |
| | L (27) | 51,9 (14) | 33,3 (9) | 14,8 (4) |
| 9.4.1 Loudness and pitch | T (171) | 22,8 (39) | 63,2 (108) | 12,3 (21) |
| | L (27) | 25,9 (7) | 55,6 (15) | 18,5 (5) |
| 9.4.2 Noise and musical notes | T (171) | 15,8 (27) | 67,8 (116) | 15,8 (27) |
| | L (27) | 25,9 (7) | 55,6 (15) | 18,5 (5) |
| 10.1 Light transfers energy | T (171) | 62,6 (107) | 36,3 (62) | 0 (0) |
| | L (28) | 75,0 (21) | 25,0 (7) | 0 (0) |
| 10.2 How light travels (transmission of light) | T (171) | 55,0 (94) | 41,5 (71) | 1,8 (3) |
| | L (28) | 60,7 (17) | 35,7 (10) | 3,6 (1) |
| 10.3 Rectilinear propagation of light | T (171) | 57,3 (98) | 39,8 (68) | 1,2 (2) |
| | L (28) | 82,1 (23) | 17,9 (5) | 0 (0) |
| 10.4 Reflection | T (171) | 59,6 (102) | 36,8 (63) | 1,2 (2) |
| | L (28) | 82,1 (23) | 17,9 (5) | 0 (0) |

| CONTENT | | | Essential | Desirable | Unneces- sary |
|---------|---------------------------------------|-------|-----------|-----------|------------------|
| 10.5 | Refraction | T | 62,6% | 34,5% | 1,2% |
| | | (171) | (107) | (59) | (2) |
| | | L | 82,1 | 17,9 | 0 |
| | | (28) | (23) | (5) | (0) |
| 10.6 | Prisms | T | 60,2 | 37,4 | 1,2 |
| | | (171) | (103) | (64) | (2) |
| | | L | 60,7 | 39,3 | 0 |
| | | (28) | (17) | (11) | (0) |
| 10.7 | Lenses | T | 63,2 | 35,7 | 0,6 |
| | | (171) | (108) | (61) | (1) |
| | | L | 75,0 | 25,0 | 0 |
| | | (28) | (21) | (7) | (0) |
| 10.8 | Diffraction and interference | T | 67,3 | 31,0 | 1,2 |
| | | (171) | (115) | (53) | (2) |
| | | L | 39,3 | 35,7 | 25,0 |
| | | (28) | (11) | (10) | (7) |
| 10.9 | Colour of light | T | 64,9 | 34,5 | 0 |
| | | (171) | (111) | (59) | (0) |
| | | L | 46,4 | 53,6 | 0 |
| | | (28) | (13) | (15) | (0) |
| 10.10 | Electromagnetic waves | T | 56,1 | 38,0 | 5,3 |
| | | (171) | (96) | (65) | (9) |
| | | L | 35,7 | 42,9 | 21,4 |
| | | (28) | (10) | (12) | (6) |
| 10.11 | Light as an elec- tromagnetic wave | T | 60,2 | 33,3 | 5,8 |
| | | (171) | (103) | (57) | (10) |
| | | L | 28,6 | 42,9 | 28,6 |
| | | (28) | (8) | (12) | (8) |
| 10.12 | The electromagnetic spectrum | T | 53,8 | 39,8 | 5,8 |
| | | (171) | (92) | (68) | (10) |
| | | L | 46,4 | 42,9 | 10,7 |
| | | (28) | (13) | (12) | (3) |
| 11.1 | The particle nature of matter | T | 57,3 | 30,4 | 11,1 |
| | | (171) | (98) | (52) | (19) |
| | | L | 71,1 | 26,3 | 2,6 |
| | | (38) | (27) | (10) | (1) |

| CONTENT | | | Essential | Desirable | Unneces- sary |
|---------|--|-------|-----------|-----------|------------------|
| 11.2 | Particle nature of electrons and photons | T | 55,0% | 26,3% | 16,4% |
| | | (171) | (94) | (45) | (28) |
| | | L | 42,1 | 42,1 | 15,8 |
| | | (38) | (16) | (16) | (6) |
| 11.3 | Wave nature of electrons and photons | T | 52,0 | 28,1 | 18,1 |
| | | (171) | (89) | (48) | (31) |
| | | L | 31,6 | 47,4 | 21,1 |
| | | (38) | (12) | (18) | (8) |
| 11.4 | Quantisation of energy as explana- tion of line spectra | T | 60,8 | 23,4 | 15,2 |
| | | (171) | (104) | (40) | (26) |
| | | L | 15,8 | 60,5 | 23,7 |
| | | (38) | (6) | (23) | (9) |

TABLE 13.4 RESPONSES OF TEACHERS AND UNIVERSITY LECTURERS TO QUESTIONS ON CONTENT: WAVES AND WAVE-PHENOMENA

2.6 The physics content - the atom

This section comprises two units, viz.

12. The atomic nucleus.

13. Atomic structure.

The latter unit is often classified as part of the chemistry content, but a sharp division between the two components is not possible.

| CONTENT | | | Essential | Desirable | Unneces- sary |
|---------|--|-------|-----------|-----------|------------------|
| 12.1 | Rutherford's scattering experi- ment | T | 44,4% | 43,9% | 10,5% |
| | | (171) | (76) | (75) | (18) |
| | | L | 40,5 | 47,6 | 9,5 |
| | | (42) | (17) | (20) | (4) |
| 12.2 | Natural radio- activity | T | 31,6 | 47,4 | 19,9 |
| | | (171) | (54) | (81) | (34) |
| | | L | 38,1 | 57,1 | 4,8 |
| | | (42) | (16) | (24) | (2) |
| 12.3 | Artificial radio- activity | T | 29,8 | 42,7 | 26,9 |
| | | (171) | (51) | (73) | (46) |
| | | L | 16,7 | 73,8 | 7,1 |
| | | (42) | (7) | (31) | (3) |
| 12.4 | Mass and energy in nuclear reactions | T | 20,5 | 44,4 | 34,5 |
| | | (171) | (35) | (76) | (59) |
| | | L | 16,7 | 64,3 | 11,9 |
| | | (42) | (7) | (27) | (5) |
| 12.5 | The energy of the sun | T | 19,9 | 44,4 | 35,1 |
| | | (171) | (34) | (76) | (60) |
| | | L | 14,3 | 59,5 | 19,0 |
| | | (42) | (6) | (25) | (8) |
| 12.6 | Particle accele- rators | T | 13,5 | 45,6 | 40,4 |
| | | (171) | (23) | (78) | (69) |
| | | L | 2,4 | 47,6 | 45,2 |
| | | (42) | (1) | (20) | (19) |
| 12.7 | Nuclear fission | T | 13,5 | 50,3 | 35,7 |
| | | (171) | (23) | (86) | (61) |
| | | L | 9,5 | 69,0 | 19,0 |
| | | (42) | (4) | (29) | (8) |

| CONTENT | | | Essential | Desirable | Unneces- sary |
|---------|--|-------|-----------|-----------|------------------|
| 12.8 | Chain reactions | T | 12,3% | 50,3% | 36,3% |
| | | (171) | (21) | (86) | (62) |
| | | L | 9,5 | 66,7 | 19,0 |
| | | (42) | (4) | (28) | (8) |
| 12.9 | Nuclear fusion | T | 7,6 | 43,3 | 41,5 |
| | | (171) | (13) | (74) | (71) |
| | | L | 11,9 | 73,8 | 9,5 |
| | | (42) | (5) | (31) | (4) |
| 13.1 | Revision of junior work and expansion of terminology on atomic structure | T | 59,1 | 33,3 | 4,7 |
| | | (171) | (101) | (57) | (8) |
| | | L | 69,8 | 18,6 | 7,0 |
| | | (43) | (30) | (8) | (3) |
| 13.2 | Development of atomic models | T | 65,5 | 33,3 | 0 |
| | | (171) | (112) | (57) | (0) |
| | | L | 34,9 | 55,8 | 9,3 |
| | | (43) | (15) | (24) | (4) |
| 13.3 | Quantum numbers | T | 74,9 | 19,3 | 4,1 |
| | | (171) | (128) | (33) | (7) |
| | | L | 16,3 | 37,2 | 46,5 |
| | | (43) | (7) | (16) | (20) |
| 13.4 | Orbitals | T | 82,5 | 15,2 | 1,8 |
| | | (171) | (141) | (26) | (3) |
| | | L | 18,6 | 32,6 | 48,8 |
| | | (43) | (8) | (14) | (21) |
| 13.5 | Aufbau | T | 80,1 | 15,2 | 1,8 |
| | | (171) | (137) | (26) | (3) |
| | | L | 18,6 | 32,6 | 48,8 |
| | | (43) | (8) | (14) | (21) |
| 13.6 | Electronic structure and the Periodic Table | T | 80,7 | 15,8 | 1,2 |
| | | (171) | (138) | (27) | (2) |
| | | L | 39,5 | 30,2 | 23,3 |
| | | (43) | (17) | (13) | (10) |
| 13.7 | Valency | T | 88,9 | 9,4 | 0 |
| | | (171) | (152) | (16) | (0) |
| | | L | 51,2 | 20,9 | 16,3 |
| | | (43) | (22) | (9) | (7) |

TABLE 13.5 RESPONSES OF TEACHERS AND UNIVERSITY LECTURERS TO QUESTIONS ON CONTENT: THE ATOM

2.7 The chemistry content - chemical bonding

This section contains the single unit

14. Chemical bonding.

| CONTENT | | Essential | Desirable | Unneces- sary |
|--------------------------------|------------|----------------|--------------|------------------|
| 14.1 The concept "molecule" | T (171) | 89,5% (153) | 9,4% (16) | 0% (0) |
| | L (26) | 88,5 (23) | 11,5 (3) | 0 (0) |
| 14.2 Covalent bond model | T (171) | 88,3 (151) | 9,4 (16) | 0,6 (1) |
| | L (26) | 50,0 (13) | 26,9 (7) | 23,1 (6) |
| 14.3 Molecular geometry | T (171) | 63,2 (108) | 31,0 (53) | 4,1 (7) |
| | L (26) | 15,4 (4) | 59,7 (15) | 26,9 (7) |
| 14.4 Polar covalent bonding | T (171) | 85,4 (146) | 13,5 (23) | 0 (0) |
| | L (26) | 23,1 (6) | 42,3 (11) | 23,1 (6) |
| 14.5 Ionic bond model | T (171) | 88,9 (152) | 9,4 (16) | 0 (0) |
| | L (26) | 46,2 (12) | 26,9 (7) | 19,2 (5) |
| 14.6 Metallic bonding | T (171) | 79,5 (136) | 18,1 (31) | 1,2 (2) |
| | L (26) | 30,8 (8) | 34,6 (9) | 26,9 (7) |
| 14.7 Intermolecular forces | T (171) | 70,8 (121) | 24,0 (41) | 4,1 (7) |
| | L (26) | 26,9 (7) | 53,8 (14) | 11,5 (3) |

TABLE 13.6 RESPONSES OF TEACHERS AND UNIVERSITY LECTURERS TO QUESTIONS ON CONTENT: CHEMICAL BONDING

2.8 The chemistry content - matter and energy

Two units, one from physics and one from chemistry, are included in this section:

15. Heat, work and internal energy.
16. Three phases of matter.

They are grouped together since both units are based on concepts derived from thermodynamics.

| CONTENT | | | Essential | Desirable | Unneces- sary |
|---------|--|------------|---------------|---------------|------------------|
| 15.1 | Effects of change in temperature | T (171) | 32,7% (56) | 53,2% (91) | 12,3% (21) |
| | | L (38) | 84,2 (32) | 10,5 (4) | 0 (0) |
| 15.2 | Heat - a form of energy | T (171) | 39,8 (68) | 48,0 (82) | 10,5 (18) |
| | | L (38) | 92,1 (35) | 7,9 (3) | 0 (0) |
| 15.3 | Equivalence of heat and work | T (171) | 38,0 (65) | 50,9 (87) | 9,4 (16) |
| | | L (38) | 81,6 (31) | 18,4 (7) | 0 (0) |
| 15.4 | Rise in temperature due to work | T (171) | 42,7 (73) | 42,7 (73) | 13,5 (23) |
| | | L (38) | 68,4 (26) | 28,9 (11) | 0 (0) |
| 15.5 | Rise in temperature by heat transfer | T (171) | 45,0 (77) | 40,4 (69) | 12,9 (22) |
| | | L (38) | 73,7 (28) | 26,3 (10) | 0 (0) |
| 15.6 | Heat capacity and specific heat capacity | T (171) | 35,7 (61) | 46,2 (79) | 15,8 (27) |
| | | L (38) | 63,2 (24) | 34,2 (13) | 2,6 (1) |
| 15.7 | Internal energy and thermal energy | T (171) | 31,0 (53) | 50,9 (87) | 17,0 (29) |
| | | L (38) | 47,4 (18) | 34,2 (13) | 15,8 (6) |

| CONTENT | | | Essential | Desirable | Unneces- sary |
|---------|---|------------|---------------|---------------|------------------|
| 15.8 | Fusion, evaporation, condensation and latent heat | T (171) | 36,8% (63) | 50,3% (86) | 12,3% (21) |
| | | L (38) | 73,7 (28) | 26,3 (10) | 0 (0) |
| 16.1 | Resumé of the kinetic-molecular theory of matter | T (171) | 52,0 (89) | 39,8 (68) | 1,8 (3) |
| | | L (39) | 69,2 (27) | 23,1 (9) | 7,7 (3) |
| 16.2.1 | The ideal gas; gas laws; Kelvin scale of tempera- ture; S.T.P. | T (171) | 60,2 (103) | 35,1 (60) | 3,5 (6) |
| | | L (39) | 79,5 (31) | 12,8 (5) | 7,7 (3) |
| 16.2.2 | Non-ideal gases | T (171) | 44,4 (76) | 46,2 (79) | 8,2 (14) |
| | | L (39) | 12,8 (5) | 53,8 (21) | 33,3 (13) |
| 16.2.3 | Calculations based on the gas laws | T (171) | 55,6 (95) | 40,9 (70) | 1,8 (3) |
| | | L (39) | 69,2 (27) | 23,1 (9) | 5,1 (2) |
| 16.3 | Liquids | T (171) | 41,5 (71) | 50,3 (86) | 7,0 (12) |
| | | L (39) | 46,2 (18) | 41,0 (16) | 7,7 (3) |
| 16.4.1 | The concept "lattice" | T (171) | 40,9 (70) | 52,0 (89) | 5,8 (10) |
| | | L (39) | 25,6 (10) | 56,4 (22) | 12,8 (5) |
| 16.4.2 | Bonding in solids | T (171) | 43,9 (75) | 48,0 (82) | 7,0 (12) |
| | | L (39) | 20,5 (8) | 59,0 (23) | 17,9 (7) |
| 16.5 | Phase equilibrium | T (171) | 54,4 (93) | 33,3 (57) | 9,4 (16) |
| | | L (39) | 25,6 (10) | 38,5 (15) | 28,2 (11) |

TABLE 13.7 RESPONSES OF TEACHERS AND UNIVERSITY LECTURERS TO QUESTIONS ON CONTENT: MATTER AND ENERGY

2.9 The chemistry content - solutions

This section contains only one short unit:

17. Solutions.

| CONTENT | | | Essential | Desirable | Unneces- sary |
|---------|--|------------|---------------|---------------|------------------|
| 17.1 | The nature of a solution | T (171) | 51,5% (88) | 40,4% (69) | 7,0% (12) |
| | | L (23) | 78,3 (18) | 21,7 (5) | 0 (0) |
| 17.2 | Intermolecular forces and solubility | T (171) | 55,0 (94) | 36,3 (62) | 7,0 (12) |
| | | L (23) | 26,1 (6) | 56,5 (13) | 13,0 (3) |
| 17.3 | Ion formation in solutions (dissociation and ionisation) | T (171) | 60,2 (103) | 29,8 (51) | 8,2 (14) |
| | | L (23) | 60,9 (14) | 30,4 (7) | 4,3 (1) |
| 17.4 | Hydration and hydration energy | T (171) | 36,8 (63) | 39,8 (68) | 22,8 (39) |
| | | L (23) | 4,3 (1) | 52,2 (12) | 39,1 (9) |
| 17.5 | Concentration of solutions; standard solutions | T (171) | 69,6 (119) | 26,3 (45) | 2,9 (5) |
| | | L (23) | 78,3 (18) | 21,7 (5) | 0 (0) |

TABLE 13.8 RESPONSES OF TEACHERS AND UNIVERSITY LECTURERS TO QUESTIONS ON CONTENT: SOLUTIONS

2.10 The chemistry content - chemical kinetics

This section contains one unit named

18. Rates of chemical reactions.

| CONTENT | | | Essential | Desirable | Unneces- sary |
|---------|---|------------|----------------|---------------|------------------|
| 18.1 | Factors affecting the rates of reactions | T (171) | 68,4% (117) | 27,5% (47) | 2,9% (5) |
| | | L (24) | 29,2 (7) | 66,7 (16) | 4,2 (1) |
| 18.2 | Collision theory | T (171) | 50,3 (86) | 36,3 (62) | 12,3 (21) |
| | | L (24) | 8,3 (2) | 50,0 (12) | 37,5 (9) |
| 18.3 | Activation energy and the activated complex | T (171) | 47,4 (81) | 37,4 (64) | 14,0 (24) |
| | | L (24) | 8,3 (2) | 33,3 (8) | 54,2 (13) |
| 18.4 | Importance of the slowest (rate determining) step | T (171) | 30,4 (52) | 44,4 (76) | 23,4 (40) |
| | | L (24) | 8,3 (2) | 25,0 (6) | 58,3 (14) |
| 18.5 | Exothermic and endothermic reactions | T (171) | 60,2 (103) | 34,5 (59) | 4,1 (7) |
| | | L (24) | 37,5 (9) | 41,7 (10) | 12,5 (3) |

TABLE 13.9 RESPONSES OF TEACHERS AND UNIVERSITY LECTURERS TO QUESTIONS ON CONTENT: CHEMICAL KINETICS

2.11 The chemistry content - chemical equilibrium

The two units included in this section are

19. Equilibrium in chemical reactions.
20. Acid-base models.

| CONTENT | | | Essential | Desirable | Unneces- sary |
|---------|---|------------|----------------|---------------|------------------|
| 19.1 | Dynamic nature of chemical equilibrium; reversible reactions | T (171) | 70,8% (121) | 25,1% (43) | 2,9% (5) |
| | | L (22) | 54,5 (12) | 45,5 (10) | 0 (0) |
| 19.2 | The equilibrium constant | T (171) | 60,2 (103) | 29,8 (51) | 8,2 (14) |
| | | L (22) | 27,3 (6) | 50,0 (11) | 22,7 (5) |
| 19.3 | Application of equilibrium principles in industry | T (171) | 52,0 (89) | 42,7 (73) | 4,7 (8) |
| | | L (22) | 18,2 (4) | 77,3 (17) | 0 (0) |
| 19.4 | Factors affecting equilibrium | T (171) | 73,7 (126) | 22,2 (38) | 2,9 (5) |
| | | L (22) | 36,4 (8) | 63,6 (14) | 0 (0) |
| 19.5 | Energy and the equilibrium condition | T (171) | 46,8 (80) | 35,7 (61) | 17,0 (29) |
| | | L (22) | 13,6 (3) | 36,4 (8) | 50,0 (11) |
| 19.6 | Entropy and the equilibrium condition | T (171) | 33,9 (58) | 35,1 (60) | 29,8 (51) |
| | | L (22) | 4,5 (1) | 27,3 (6) | 68,2 (15) |
| 19.7 | Equilibrium - a compromise between energy and entropy factors | T (171) | 25,7 (44) | 42,1 (72) | 31,0 (53) |
| | | L (22) | 4,5 (1) | 31,8 (7) | 63,6 (14) |
| 19.8 | Equilibrium in solutions: solubility product | T (171) | 37,4 (64) | 38,6 (66) | 22,8 (39) |
| | | L (22) | 18,2 (4) | 45,5 (10) | 31,8 (7) |

| CONTENT | | | Essential | Desirable | Unneces- sary |
|---------|--|------------|----------------|---------------|------------------|
| 19.9 | Acid-base- equilibria | T (171) | 77,2% (132) | 19,9% (34) | 0,6% (1) |
| | | L (22) | 72,7 (16) | 27,3 (6) | 0 (0) |
| 19.10 | Ionisation of water | T (171) | 64,9 (111) | 28,0 (48) | 5,3 (9) |
| | | L (22) | 68,2 (15) | 27,3 (6) | 4,5 (1) |
| 20.1 | Arrhenius model of acids and bases | T (171) | 34,5 (59) | 42,7 (73) | 22,2 (38) |
| | | L (22) | 54,5 (12) | 22,7 (5) | 13,6 (3) |
| 20.2 | Lowry-Bronsted model; protolysis | T (171) | 78,4 (134) | 19,9 (34) | 0 (0) |
| | | L (22) | 50,0 (11) | 31,8 (7) | 13,6 (3) |
| 20.3 | Acid-base titra- tions | T (171) | 81,3 (139) | 14,6 (25) | 2,3 (4) |
| | | L (22) | 68,2 (15) | 13,6 (3) | 13,6 (3) |
| 20.4 | pH | T (171) | 85,4 (146) | 12,3 (21) | 0,6 (1) |
| | | L (22) | 59,1 (13) | 36,4 (8) | 4,5 (4) |
| 20.5 | Trends in the acid-base proper- ties of the hy- droxides of Period 3 | T (171) | 30,4 (52) | 37,4 (64) | 30,4 (52) |
| | | L (22) | 22,7 (5) | 54,5 (12) | 18,2 (4) |

TABLE 13.10 RESPONSES OF TEACHERS AND UNIVERSITY LECTURERS TO QUESTIONS ON CONTENT: CHEMICAL EQUILIBRIUM

2.12 The chemistry content - electrochemistry and oxidation-reduction

The two units included in this section are

21. Electrochemical cells.
22. Oxidation-reduction.

| CONTENT | | | Essential | Desirable | Unneces- sary |
|---------|---|-------|-----------|-----------|------------------|
| 21.1 | The Cu-Zn cell and its chemistry | T | 86,5% | 12,3% | 0% |
| | | (171) | (148) | (21) | (0) |
| | | L | 36,4 | 54,5 | 4,5 |
| | | (22) | (8) | (12) | (1) |
| 21.2 | Half-cell reactions; electrons in half-cell reactions; net reaction | T | 86,5 | 11,7 | 0 |
| | | (171) | (148) | (20) | (0) |
| | | L | 22,7 | 63,6 | 4,5 |
| | | (22) | (5) | (14) | (1) |
| 21.3 | Oxidation-reduction in terms of electrons | T | 88,3 | 10,5 | 0 |
| | | (171) | (151) | (18) | (0) |
| | | L | 63,6 | 36,4 | 0 |
| | | (22) | (14) | (8) | (0) |
| 21.4 | Half-cell potentials | T | 77,8 | 17,0 | 4,1 |
| | | (171) | (133) | (29) | (7) |
| | | L | 18,2 | 54,5 | 27,3 |
| | | (22) | (4) | (12) | (6) |
| 21.5 | Standard electrode potentials | T | 70,8 | 22,8 | 5,3 |
| | | (171) | (121) | (38) | (9) |
| | | L | 22,7 | 45,5 | 31,8 |
| | | (22) | (5) | (10) | (7) |
| 21.6 | Corrosion | T | 15,2 | 50,3 | 33,9 |
| | | (171) | (26) | (86) | (58) |
| | | L | 22,7 | 54,5 | 22,7 |
| | | (22) | (5) | (12) | (5) |
| 21.7 | Electrolytic cells; electrolysis | T | 45,6 | 39,8 | 12,9 |
| | | (171) | (78) | (68) | (22) |
| | | L | 54,5 | 45,5 | 0 |
| | | (22) | (12) | (10) | (0) |

| CONTENT | | | Essential | Desirable | Unneces- sary |
|---------|---|------------|----------------|---------------|------------------|
| 22.1 | Oxidation-reduction as electron transfer half-reaction method of balancing equations | T (171) | 81,3% (139) | 15,8% (27) | 1,8% (3) |
| | | L (21) | 52,4 (11) | 38,1 (8) | 9,5 (2) |
| 22.2 | Oxidation numbers: oxidation number method of balancing equations | T (171) | 72,5 (124) | 22,2 (38) | 4,1 (7) |
| | | L (21) | 23,8 (5) | 66,7 (14) | 9,5 (2) |
| 22.3 | Trend in oxidising and reducing properties of elements in Groups I and VII and Period 3 | T (171) | 33,9 (58) | 47,4 (81) | 17,0 (29) |
| | | L (21) | 33,3 (7) | 47,6 (10) | 19,0 (4) |
| 22.4 | Oxidation-reduction properties of selected transition elements | T (171) | 19,9 (34) | 43,3 (74) | 35,1 (60) |
| | | L (21) | 9,5 (2) | 57,1 (12) | 33,3 (7) |

TABLE 13.11 RESPONSES OF TEACHERS AND UNIVERSITY LECTURERS TO QUESTIONS ON CONTENT: ELECTROCHEMISTRY AND OXIDATION-REDUCTION

2.13 The chemistry content - organic chemistry

This section contains a single unit on

23. Organic chemistry.

| CONTENT | | | Essential | Desirable | Unneces- sary |
|---------|---|------------|----------------|---------------|------------------|
| 23.1 | What is organic chemistry? - introduction | T (171) | 74,9% (128) | 12,9% (22) | 9,9% (17) |
| | | L (22) | 63,6 (14) | 27,3 (6) | 4,5 (1) |
| 23.2 | Structures of compounds | T (171) | 73,7 (126) | 15,8 (27) | 8,8 (15) |
| | | L (22) | 45,5 (10) | 27,3 (6) | 27,3 (6) |
| 23.3 | Nomenclature (IUPAC) | T (171) | 70,8 (121) | 17,0 (29) | 9,9 (17) |
| | | L (22) | 36,4 (8) | 31,8 (7) | 27,3 (6) |
| 23.4.1 | Hydrocarbons: alkanes, alkenes, alkynes | T (171) | 69,0 (118) | 19,9 (34) | 9,9 (17) |
| | | L (22) | 31,8 (7) | 37,5 (9) | 27,3 (6) |
| 23.4.2 | Halo-alkanes | T (171) | 63,2 (108) | 25,1 (43) | 9,9 (17) |
| | | L (22) | 31,8 (7) | 36,4 (8) | 31,8 (7) |
| 23.4.3 | Alcohols | T (171) | 66,1 (113) | 22,2 (38) | 9,9 (17) |
| | | L (22) | 31,8 (7) | 37,5 (9) | 27,3 (6) |
| 23.4.4 | Carboxylic acids | T (171) | 62,6 (107) | 24,0 (41) | 11,1 (19) |
| | | L (22) | 27,3 (6) | 37,5 (9) | 27,3 (6) |
| 23.4.5 | Esters | T (171) | 60,2 (103) | 24,0 (41) | 14,0 (24) |
| | | L (22) | 27,3 (6) | 36,4 (8) | 31,8 (7) |

TABLE 13.12 RESPONSES OF TEACHERS AND UNIVERSITY LECTURERS TO QUESTIONS ON CONTENT: ORGANIC CHEMISTRY

2.14. The chemistry content - inorganic chemistry

This last section does not occur in the official syllabuses but was added in order to determine whether a need for the inclusion of inorganic chemistry exists. The last unit of this section: "A study of inorganic chemistry for its own sake", was added or implied by so many lecturers that it is included in TABLE 13.13 although it does not appear in the questionnaire.

24. Systematic inorganic chemistry.

| CONTENT | | | Essential | Desirable | Unneces- sary |
|---------|--|------------|---------------|---------------|------------------|
| 24.1 | A study of selected reactions to apply the principles developed in the theory | T (171) | 48,0% (82) | 38,6% (66) | 11,1% (19) |
| | | L (22) | 37,5 (9) | 27,3 (6) | 27,3 (6) |
| 24.2 | A study of selected reactions to obtain practice in the writing and balancing of equations | T (171) | 50,3 (86) | 38,0 (65) | 11,1 (19) |
| | | L (22) | 77,3 (17) | 18,2 (4) | 4,5 (1) |
| 24.3 | Systematic inorganic chemistry (for its own sake) | T | - | - | - |
| | | L (22) | 54,5 (12) | - | - |

TABLE 13.13 RESPONSES OF TEACHERS AND UNIVERSITY LECTURERS TO QUESTIONS ON CONTENT: INORGANIC CHEMISTRY

2.15 The essential content according to teachers and lecturers

3. Electrostatics

2.15.1 Introductory

The selection of essential content is based on those topics indicated as essential by at least 50% of both teachers and lecturers. A second list of possibly essential topics is also provided. This list consists of those topics which were selected by 60% or more of one of the two groups but by only 40 - 49% of the other.

2.15.2 Essential-content

- 2.1 Electromagnetic energy
- 2.2 Vectors
- 2.1 Displacement
- 2.2 Displacement and force as examples of vectors
- 2.3 Equilibrium of forces
- 2.4 Components
- 2.5 Velocity and acceleration
3. Displacement-time and velocity-time relationships
 - 3.1 Graphic representations
 - 3.2 Experimental investigation
 - 3.3 Equations of motion
4. Bodies in motion
 - 4.1 Newton's first law
 - 4.2 Newton's second law
 - 4.4 Newton's law of universal gravitation
 - 4.5 Newton's third law
 - 4.6 Momentum
 - 4.7 Work, energy and power
5. Electrostatics
 - 5.2 Force between charges: Coulomb's law
 - 5.3 Electric fields

8. Waves

- 8.1 Vibration as introduction to periodic motion; terminology
- 8.2 Graphic representation of a disturbance versus time
- 8.3 Polarisation, extinction, superposition
- 8.5 Interference and diffraction

10. Light

- 10.9 Colour of light

23. Organic chemistry

- 23.2 Structure of compounds

2.15.4 Summary

The essential core of a syllabus for Physical Science according to the selections of teachers and lecturers, may be summarised as follows:

1. Elementary mechanics.
2. Electrostatics and current electricity.
3. Light (geometrical optics).
4. Matter (Particle nature of matter; simple atomic structure; valency).
5. Elementary chemical bonding (covalent and ionic).
6. Gases (kinetic-molecular model; gas laws; calculations).
7. Solutions (nature; ion formation; concentration).
8. Chemical equilibrium (limited to reversible reactions; acid-base equilibrium; ionisation of water).
9. Acids and bases (Lowry-Bronsted model; titrations; pH).
10. Oxidation-reduction (in terms of electron transfer only).
11. Inorganic chemistry.
12. Organic chemistry - introduction only.

Apart from some minor extensions to the topics listed above, the only other topic which may be added as being possibly essential is

13. Waves.

2.16 Content considered unnecessary according to teachers and lecturers

2.16.1 Here, too, the problem of combining the responses of the 171 teachers and a maximum of 50 lecturers arose. The first list contains those topics deemed unnecessary by teachers and lecturers on the basis of the combined raw scores. This list includes topics indicated as unnecessary by 50% or more of the combined responses. The additional list of topics which may be possibly unnecessary is based on the opinions of either teachers or lecturers.

2.16.2 Unnecessary content

The numbering used in the following list follows that of the questionnaire.

- 4.3 Circular motion.
- 7.3 Vacuum triode and applications.
- 7.4 Transistor.
- 7.5 Reception and modulation of radio waves.
- 12.5 Energy of the sun.
- 12.6 Particle accelerators.
- 12.7 Nuclear fission.
- 12.8 Chain reactions (nuclear).
- 12.9 Nuclear fusion.
- 17.4 Hydration and hydration energy.
- 19.6 Entropy and the equilibrium condition.
- 19.7 Equilibrium: a compromise between energy and entropy factors.
- 19.8 Equilibrium in solutions: solubility product.
- 21.6 Corrosion.
- 22.4 Redox properties of transition elements.

2.16.3 Possibly unnecessary content

- 7.1 Thermionic emission (Lecturers: 50%).
- 7.2 Thermionic diode and applications (Lecturers: 64,3%)
- 13.3 Quantum numbers (Lecturers: 46,5%)
- 13.4 Orbitals (Lecturers: 48,8%)
- 13.5 Aufbau (Lecturers: 48,8%)
- 19.5 Energy and the equilibrium condition (Lecturers: 50%).

2.16.4 Conclusion

Out of the 133 syllabus topics listed in the questionnaire 51 (38,5%) are considered to be essential, 15 topics (11,3%) are considered unnecessary, and 53 topics (39,8%) may be classified as "desirable". The different categories are summarised in TABLE 13.14.

| Classification of content | Number | Percentage | Total |
|---------------------------|--------|------------|-------|
| 1. ESSENTIAL | 51 | 38,5 | 44,4% |
| 2. POSSIBLY ESSENTIAL | 8 | 6,0 | |
| 3. DESIRABLE | 53 | 39,8 | 39,8 |
| 4. UNNECESSARY | 15 | 11,3 | 15,8 |
| 5. POSSIBLY UNNECESSARY | 6 | 4,5 | |
| TOTAL (Number of topics) | 133 | 100,1 | 100,0 |

TABLE 13.14 CLASSIFICATION OF CONTENT ACCORDING TO TEACHERS AND LECTURERS

The fact that less than one half (44,4%) of the syllabus topics are regarded as essential and that very nearly a sixth (15,8%) of the topics are considered to be unnecessary, indicates that the syllabus content is unsatisfactory in the opinions of both teachers and lecturers.

This conclusion is supported by the comments supplied by the respondents, as exemplified by the following abstracts:

1. "I would favour a smaller syllabus concentrating on those topics which can be quantitatively dealt with, and with greater depth of treatment of these topics and their applications in everyday life. This implies an emphasis on mechanics, current electricity, heat and light, and while this may seem old-fashioned I believe that there is no substitute for a solid grounding in these topics, and I further believe that they can be both challenging and interesting. I agree that pupils should be exposed to "modern physics" as well, but I think that this should be a subsidiary part of the syllabus." (Physics Lecturer, Cape Town).
2. "What should essentially be attained with physics at school?
 1. Development of the basic concepts of force, work and energy in mechanics, and carrying these concepts through to electricity and other areas such as heat and gases ...
 2. A thorough development of the idea of wave motion and simple applications in strings and sound.
 3. A general understanding of the composition of the atom and nucleus and radiations from the atom and nucleus.
 4. Everyday physics, such as properties of matter (heat capacity, linear coefficient of expansion, adhesion, cohesion, Archimedes' law, viscosity, surface tension, ... refractive index, laws of reflection and refraction of light, formation of images by lenses and mirrors, etc. ...
 5. Simple applications should always be included in the development of the areas 1 to 4 above ...
 6. Modern physics and technology ... should be included in the programme as laboratory demonstrations or as projects and assignments to pupils, but not for examination purposes." (Physics lecturer, Potchefstroom).
3. "I do not consider it necessary for the school syllabus, as far as chemistry is concerned, to deal with atomic structure at all ...

I consider the first essential is simple chemistry of simple materials; then after this a study of some historical chemistry to see how ideas evolved, important both for the ideas and as a study of the history and methodology of science (law of constant composition, law of multiple proportions, idea of valency, ...). Balancing of equations, simple titrations, simple study of the gas laws and of the law of mass action (equilibrium of gaseous reactions ...) can all find a place but I should prefer to keep more complex theories right out ..."
(Chemistry lecturer, Natal (Durban)).

4. "My general feeling is that there should be less emphasis on some of the more difficult conceptual material (atomic orbitals, titrations, activation energy, transition states) and more emphasis in the syllabus of what is of importance to the chemical industry, especially in S.A. The chemical industry handles largely simple compounds (and reactions) e.g. H_2SO_4 , HNO_3 , NH_3 , CO_2 , H_2O , O_2 , N_2 , NH_4NO_3 , CaCO_3 , NaOH , NaCl , AlF_3 , Cl_2 , CH_4 , C_2H_4 , CH_3OH , CH_3CHO , etc.

I do not advocate returning to rote learning of 'systematic inorganic chemistry' nor do I believe that chemistry is 'colours, bangs, and smells'. While the latter have their use in demonstrations and experiments as being (possibly) motivational, it would be dishonest to let pupils get the impression that this is what contemporary chemistry is about." (Chemistry lecturer, Witwatersrand).

2.17 The interest value of the content

- 2.17.1 The essential core of topics forming the backbone of the study of chemistry and physics, is not the only important factor to be considered in the evaluation of the syllabus content. If pupils are to learn effectively, the content should also be inherently interesting and it should be possible to teach it in such a way, i.e. to design teaching-learning activities, that the interest of the pupils can be obtained and maintained.

2.17.2 The interest value according to pupils

Because of the severe reduction in scope of the original questionnaire for pupils (the reasons for which were detailed in Chapter 11) pupils were only asked to indicate whether they considered the syllabus as a whole "very interesting", "interesting in parts only", or "uninteresting". Their responses are summarised in TABLE 13.15.

| | STANDARD GRADE | | | HIGHER GRADE | | | BOTH GRADES | | |
|----------------------|----------------|-------|-------|--------------|-------|-------|-------------|-------|-------|
| | Boys | Girls | Total | Boys | Girls | Total | Boys | Girls | Total |
| | 256 | 104 | 360 | 607 | 252 | 859 | 863 | 356 | 1 219 |
| Very interesting | 21,5 | 14,4 | 19,4 | 21,1 | 22,2 | 21,1 | 21,1 | 19,9 | 20,8% |
| | 55 | 15 | 70 | 128 | 56 | 184 | 183 | 71 | 254 |
| Interesting in parts | 70,7 | 80,8 | 73,6 | 70,0 | 67,1 | 69,2 | 70,2 | 71,1 | 70,5% |
| | 181 | 84 | 265 | 425 | 169 | 594 | 606 | 253 | 859 |
| Uninteresting | 0,8 | 2,9 | 1,4 | 0,0 | 3,6 | 1,0 | 0,2 | 3,4 | 1,1% |
| | 2 | 3 | 5 | 0 | 9 | 9 | 2 | 12 | 14 |
| Uncertain | 7,0 | 1,9 | 5,6 | 8,9 | 7,1 | 8,4 | 8,3 | 5,6 | 7,5% |
| | 18 | 2 | 20 | 54 | 18 | 72 | 72 | 20 | 92 |

TABLE 13.15 INTEREST VALUE OF THE SYLLABUS ACCORDING TO PUPILS

To determine whether there is a difference of interest in the two components of the syllabus - physics and chemistry - pupils were asked to indicate which section they found more interesting.

| | STANDARD GRADE | | | HIGHER GRADE | | | BOTH GRADES | | |
|-------------|----------------|-------|-------|--------------|-------|-------|-------------|-------|-------|
| | Boys | Girls | Total | Boys | Girls | Total | Boys | Girls | Total |
| | 256 | 104 | 360 | 607 | 252 | 859 | 863 | 356 | 1 219 |
| Physics | 60,5 | 41,3 | 55,0 | 63,4 | 42,5 | 57,3 | 62,6 | 42,1 | 56,6% |
| | 155 | 43 | 198 | 385 | 107 | 492 | 540 | 150 | 690 |
| Chemistry | 38,7 | 57,7 | 44,2 | 35,1 | 56,0 | 41,2 | 36,2 | 56,5 | 42,1% |
| | 99 | 60 | 159 | 213 | 141 | 354 | 312 | 201 | 513 |
| No response | 0,8 | 1,0 | 0,8 | 1,5 | 1,6 | 1,5 | 1,3 | 1,4 | 1,3% |
| | 2 | 1 | 3 | 9 | 4 | 13 | 11 | 5 | 16 |

TABLE 13.16 COMPARISON OF THE INTEREST VALUE OF PHYSICS AND CHEMISTRY

There is very little difference between the responses of higher grade and standard grade pupils and between girls and boys regarding the interest value of the syllabus as a whole. Approximately 20% of all pupils find the syllabus very interesting, approximately 70% find it only interesting in parts, and about 1% thinks that the syllabus is uninteresting.

Approximately 57% of the pupils find the physics more interesting, while approximately 42% find chemistry more interesting. Here, too, there is very little difference between Higher and Standard Grade, although there is a significant difference by sex. Boys find physics more interesting than chemistry (62,6 : 36,2), whereas the reverse is true of girls (42,1 : 56,5).

2.17.3 The interest value according to teachers

Teachers were requested (a) to indicate whether the content is interesting to the majority of pupils, and (b) to evaluate the interest value of the different syllabus topics on a three-point scale, viz.

| | |
|-------------------------|----|
| high interest value | 1 |
| moderate interest value | 2 |
| low interest value | 3. |

An interest index was calculated on the basis of the frequencies of the teachers' responses and the interest value was then classified according to an equal-interval scale, as follows:

| <u>Index</u> | <u>Interest value</u> |
|--------------|-----------------------|
| 1,0 - 1,6 | High |
| >1,6 - 2,3 | Moderate |
| >2,3 - 3,0 | Low |

The results obtained from questions (a) and (b) above, are summarised in TABLES 13.17 AND 13.18 respectively. .

| EVALUATION | Number | Percentage |
|---|--------|------------|
| 1. Majority of pupils find the syllabus content INTERESTING | 137 | 80,1 |
| 2. Majority of pupils find the syllabus content UNINTERESTING | 31 | 18,1 |
| No response | 3 | 1,8 |
| TOTAL | 171 | 100,0 |

TABLE 13.17 THE INTEREST VALUE OF SYLLABUS CONTENT ACCORDING TO TEACHERS

| Standard | Topic | Index | Interest value |
|----------------------|--|----------|----------------|
| 8 | 1. Light | 1,70 | Moderate |
| | 2. Sound | 1,85 | Moderate |
| | 3. Heat, work and internal energy | 2,42 | Low |
| | 4. Electricity | 1,30 | High |
| | 5. Atomic structure | 1,68 | Moderate |
| | 6. Chemical reactions | 1,52 | High |
| | 7. Acids, bases and salts | 1,51 | High |
| | 8. Chemical reactions and electricity | 1,46 | High |
| | 9. Reactions involving ions | 1,91 | Moderate |
| 9 | 1. Vectors | 2,11 | Moderate |
| | 2. Displacement-time and velocity-time relationships | 1,89 | Moderate |
| | 3. Bodies in motion | 1,60 | High |
| | 4. Electrostatics | 1,86 | Moderate |
| | 5. The electric current | 1,56 | High |
| | 6. Thermionic emission | 1,44 | High |
| | 7. Light | 1,73 | Moderate |
| | 8. Electromagnetic waves | 2,12 | Moderate |
| | 9. Particles, waves and quanta | 2,31 | Low |
| | 10. The atomic nucleus | 1,67 | Moderate |
| | 11. Atomic structure | 1,63 | Moderate |
| 10 | 1. Chemical bonding | 1,89 | Moderate |
| | 2. Three phases of matter | 2,30 | Moderate |
| | 3. Solutions | 2,13 | Moderate |
| | 4. Rate of chemical reactions | 1,92 | Moderate |
| | 5. Equilibrium in chemical reactions | 1,78 | Moderate |
| | 5.a Acid-base models | 1,50 | High |
| | 6. Electrochemical cells | 1,43 | High |
| | 7. Oxidation-reduction | 1,70 | Moderate |
| 8. Organic chemistry | 1,73 | Moderate | |

TABLE 13.18 THE INTEREST VALUE OF DIFFERENT SYLLABUS TOPICS ACCORDING TO TEACHERS

It should be pointed out that interest value is also directly related to the quality of the teaching. This is apparent from the observation that many of the pupils who indicated that they find the content "very interesting" were attached to particular schools.

2.18 The difficulty of the content

A number of lecturers mentioned in their comments that the syllabus topics are too sophisticated and that the majority of pupils would find the theory too difficult to understand and master. Both pupils and teachers were asked to indicate how Physical Science compares to other subjects in degree of difficulty and to indicate whether the physics or chemistry component is the more difficult. The answers to these questions are supplied in TABLES 13.19 and 13.20.

| Difficulty compared to other school subjects | TEACHERS | | PUPILS | |
|--|----------|------------|--------|------------|
| | Number | Percentage | Number | Percentage |
| 1. Easier | 0 | 0,0 | 56 | 4,6 |
| 2. About equal | 34 | 19,9 | 630 | 51,7 |
| 3. More difficult | 137 | 80,0 | 469 | 38,5 |
| No response | 0 | 0,0 | 64 | 5,3 |
| TOTAL | 171 | 99,9 | 1 219 | 100,1 |

TABLE 13.19 COMPARISON OF THE DIFFICULTY OF PHYSICAL SCIENCE IN RELATION TO OTHER SCHOOLS SUBJECTS ACCORDING TO TEACHERS AND PUPILS

There is very little difference between the opinions of pupils offering the subject on the Higher or Standard Grade, and between those of boys and girls. A slightly higher percentage of Higher Grade than Standard Grade pupils find the subject to be "easier".

| More difficult component | TEACHERS | | PUPILS | |
|--------------------------|----------|------------|--------|------------|
| | Number | Percentage | Number | Percentage |
| 1. Physics | 19 | 11,1 | 249 | 20,4 |
| 2. Chemistry | 53 | 31,0 | 957 | 78,5 |
| 3. Equal | 99 | 57,9 | (13)* | (1,1)* |
| TOTAL | 171 | 100,0 | 1 219 | 100,0 |

* No response

TABLE 13.20 RELATIVE DIFFICULTY OF PHYSICS AND CHEMISTRY ACCORDING TO TEACHERS AND PUPILS

Teachers were requested to estimate for what percentage of their senior (Standard 10) class the syllabus content is suitable, i.e. within the reasonable ability of the pupils to obtain a percentage comparable to their general class attainment. The results of these estimates are summarised in TABLE 13.21.

| The percentage of Standard 10 pupils for whom the syllabus content is considered to be suitable | Number | Percentage |
|---|--------|------------|
| 100% | 116 | 67,8 |
| Up to 90% | 125 | 73,1 |
| Up to 80% | 130 | 76,0 |
| Up to 70% | 154 | 90,0 |
| Up to 60% | 169 | 98,8 |

TABLE 13.21 PERCENTAGE OF STANDARD 10 PUPILS FOR WHOM THE SYLLABUS IS ESTIMATED TO BE SUITABLE ACCORDING TO TEACHERS

It is important to note that teachers estimate that only approximately two thirds of the Standard 10 pupils will be able to obtain a standard comparable to their general or average attainment in all other subjects.

2.19 The length of the syllabus

One of the most frequent comments made by lecturers, was that the syllabus contains too many topics and that too wide a range of work is being covered. The opinions of pupils and teachers on the length of the syllabuses for the Higher Grade and Standard Grade are reported in the following two sections.

2.19.1 The length of the syllabus according to pupils

Pupils were asked to indicate whether the course contains (a) too much work, (b) just enough work, or (c) too little work.

| Amount of work | Standard Grade | | Higher Grade | | Total | |
|----------------|----------------|-------|--------------|------|--------|-------|
| | Number | % | Number | % | Number | % |
| 1. Too much | 157 | 43,6 | 389 | 45,3 | 546 | 44,8 |
| 2. Just enough | 184 | 51,1 | 429 | 49,9 | 613 | 50,3 |
| 3. Too little | 0 | 0,0 | 9 | 1,0 | 9 | 0,7 |
| No response | 19 | 5,3 | 32 | 3,7 | 51 | 4,2 |
| TOTAL | 360 | 100,0 | 859 | 99,9 | 1 219 | 100,0 |

TABLE 13.22 PUPILS' OPINIONS ON THE LENGTH OF THE SYLLABUS

2.19.2 The length of the syllabus according to teachers

Teachers' opinions on the length of the syllabuses for Higher Grade and Standard Grade are summarised in TABLES 13.23 and 13.24.

| Length of syllabus | Higher Grade | | Standard Grade | |
|--------------------|--------------|-------|----------------|-------|
| | Number | % | Number | % |
| 1. Too long | 84 | 49,1 | 36 | 21,1 |
| 2. Reasonable | 87 | 50,9 | 126 | 73,7 |
| 3. Too short | 0 | 0,0 | 9 | 5,3 |
| TOTAL | 171 | 100,0 | 171 | 100,1 |

TABLE 13.23 TEACHERS' OPINIONS ON THE LENGTHS OF THE SYLLABUSES

There is remarkable agreement on the length of the Higher Grade syllabus among pupils and teachers.

| Approximate percentage of syllabus teachers are able to complete in Standards 9 and 10 | HIGHER GRADE | | STANDARD GRADE | |
|--|--------------|------|----------------|-------|
| | Number | % | Number | % |
| 100% | 48 | 28,1 | 97 | 56,7 |
| Up to 95% | 87 | 50,9 | 150 | 87,7 |
| Up to 90% | 150 | 87,7 | 167 | 97,7 |
| Up to 80% | 159 | 92,9 | 169 | 98,8 |
| Up to 70% | 170 | 99,4 | 171 | 100,0 |

TABLE 13.24 "APPROXIMATE PERCENTAGE OF THE SYLLABUS TEACHERS ARE ABLE TO COMPLETE

The data in TABLE 13.24 suggest that the Higher Grade syllabus seems to be too long by approximately 20 - 30% and the Standard Grade syllabus by 10 - 20%. If it is taken into account that observation shows that insufficient time is spent on practical work (see Chapter 15) and that time should be available for classroom discussion of the issues related to science and the environment and to science and society, the upper limits of these estimates (i.e. Higher Grade syllabus 30% too long and Standard Grade syllabus 20% too long) seem to be reasonable figures.

2.19.3 The influence of the length of the syllabus on teaching

The length of the syllabus is often given as the reason why teachers find it difficult to integrate a comprehensive programme of practical work with their teaching.⁵ In this regard it should be kept in mind that, according to the questionnaire, 151 teachers (88,3%) teach both Higher and Standard Grade pupils together and that only 20 (11,7%) have these groups in separate classes. The different needs of these two groups also take up valuable teaching time when they are taught together.

The question whether the length of the syllabus has a detrimental effect on their teaching of the subject, brought the following response:

| | |
|--------------|-------------|
| Yes: | 104 (60,8%) |
| No : | 65 (38,0%) |
| No response: | 2 (1,2%) |

2.20 Summary

1. Based on the opinions of teachers and lecturers the 133 topics extracted from the official syllabuses may be classified as follows:
 - (a) Essential: 51 topics (38,5%);
 - (b) desirable: 53 topics (39,8%);
 - (c) unnecessary: 15 topics (11,3%).
2. The interest value of the syllabus as a whole, according to the pupils, is as follows:
 - (a) Interesting: 20,8%
 - (b) interesting in parts: 70,5%
 - (c) uninteresting: 1,1%.
3. Teachers are of the opinion that 80,1% of pupils find the content interesting and 18,1% find it uninteresting.
4. The physics component is more interesting to boys (62,6%) whereas girls (56,5%) find the chemistry more interesting.
5. According to the teachers' evaluation of 29 syllabus units, the following is found:
 - (a) Units having a high interest value: 9 (31,0%)
 - (b) Units having a moderate interest value: 18 (62,1%)
 - (c) Units having a low interest value: 2 (6,9%).
6. 38,5% of the pupils judge Physical Science to be more difficult than their other school subjects; teachers' estimate is as high as 80%. The two groups agree that chemistry is more difficult than physics.
7. Teachers estimate that the syllabus content is suitable for approximately the upper 60% of their Standard 10 pupils.
8. Pupils and teachers agree that the syllabuses are too long (approximately 45% pupils and 49% teachers). The responses of teachers suggest that the Higher Grade syllabus is too long by ca. 20 - 30% and the Standard Grade syllabus by ca. 10 - 20%.

9. The length of the syllabus has a detrimental effect on the teaching of 60,8% of the teachers.

3. THE CRITERION-BASED EVALUATION

3.1 The criterion of validity

This criterion has two aspects, viz. (a) the content must be valid in the sense that it is appropriate to, and lends itself to the attainment of the curriculum aims, and (b) the content should be valid in that it represents authentic, true and up-to-date knowledge.

3.1.1 Validity in terms of the syllabus aims

The official syllabus aims emphasise the disciplinary nature of physics and chemistry and point to a formal, academic study. They cater for laboratory activities related to an understanding of the investigative methods used in science and for preparation for continued study in the sciences at tertiary (university) level.

The syllabus content⁶ comprises a selection from basic and modern physics arranged in a highly formal, logical sequence. The chemistry content is mainly derived from physical chemistry with the emphasis on theoretical concepts.

It may be concluded that the syllabus content is valid in the context of the official syllabus aims. The validity of the aims themselves, especially in the educational and societal contexts, is, however, suspect (Chapter 12).

3.1.2 Validity in terms of the authenticity, truth and up-to-dateness of the content

In this sense, too, the content is judged to be valid since it represents a selection from modern physics and chemistry which is currently accepted as a true reflection of the status and nature of these disciplines. The topics included show a remarkable similarity with modern undergraduate curricula in these subjects.

3.2 The criterion of significance

The two components of this criterion are (a) that the content should be significant in that it provides for the understanding of principles and concepts, and for the related, essential factual knowledge which is meaningful at the appropriate curriculum level, and (b) that the content should be significant in that it should convey the methods of the investigative procedures characteristic of the subject.

3.2.1 Significance with reference to principles and knowledge

The value placed on concepts and principles is self-evident from the detailed descriptions of the different syllabus topics. This is especially true of the chemistry component which is very nearly entirely structured on a series of theoretical concepts.

It is also obvious that the essential factual knowledge which should serve as the basis of the theory and should provide material for the illustration and application of the theoretical concepts, models and theories, is greatly lacking. Again, the chemistry component suffers heavily in this respect.

It may also be questioned whether many of the concepts - e.g. internal energy, wave-particle dualism, the wave-mechanical concept of the atom, atomic orbitals, hybridisation of orbitals, the derivation of the ideal gas temperature scale, chemical kinetics, the energy-entropy approach to chemical and phase equilibria - are meaningful, or can be made meaningful, at the age level of 15+ to 17+ years.

One is forced to conclude that the content does not comply with this aspect of significance.

3.2.2 Significance with reference to the methods of the investigative procedures of the subject areas

With the single exception of the topic "A BRIEF survey of the development of the model of the atom"⁷ no provision is made for the history of the development of ideas and concepts in physics and chemistry. Moreover, the historical development is specifically excluded:

The history of Physical Science should be drawn on only where the historical development is an aid to understanding. ⁸

Limiting the concept of "investigative procedures" to laboratory methods and techniques based on a prescribed list of experiments and demonstrations, is not conducive to developing an understanding of the investigative methods characteristic of the physical sciences. To achieve such an understanding and appreciation of these methods, provision must be made for selected aspects of the history of the growth and development of the ideas of modern science.⁹ The syllabus content thus does not comply with this aspect of the criterion of significance.

3.3 The criterion of balance

The content should represent an appropriate balance of scope (breadth of coverage) and of difficulty and complexity (presentation and understanding).

The list of physics topics (light, sound, heat, waves, mechanics, electricity, electronics, electromagnetism, electromagnetic waves, wave-particle dualism, atomic and nuclear physics, phases of matter) and the many concepts and models prescribed in chemistry (covalent, polar-covalent, ionic and hydrogen bonding, intermolecular forces, wave-mechanical model of the atom, orbital overlap, hybridisation, solubility in terms of intermolecular forces and energy of hydration, the energy-entropy model of equilibrium, collision theory, standard electrode potentials, acid-base models, electron-ion and oxidation number approaches to oxidation reduction) seem to indicate an approach aimed at covering almost every topic and theory the pupil is likely to encounter during his early undergraduate university studies, rather than making a reasoned selection of adequate scope.

This breadth of coverage must inevitably lead to superficial study and presentation and thus result in a lack of depth of understanding. Many of the topics themselves are of such an abstract and theoretical nature that proper understanding at this level of education is extremely unlikely.

The content does not succeed in providing the appropriate balance of scope and depth of understanding.

Content which may be included in the first category is material which is interesting because of its novelty and uniqueness, e.g. nuclear physics and electronics. Other topics are those which relate directly to experience, such as mechanics, electricity and aspects of optics.

The second group includes all those topics which are rich in illustration and demonstration material, and those which can readily be introduced and developed through practical work.

Most of the physics content (with the exception of such areas as wave-particle dualism, electromagnetic waves, etc.) as well as the study of inorganic and organic reactions, lend itself to a presentation which can arouse pupil interest. The more esoteric, highly theoretical topics must of necessity be presented by chalk-and-talk methods, with the aid, perhaps, of audio-visual techniques.

From this discussion one may conclude that, with some minor exceptions, the physics content complies with the criterion of interest, whereas only a few of the chemistry topics can qualify.

3.6 The criterion of consistency

According to this criterion the content should be internally consistent and non-contradictory, i.e. the various parts or topics should form a mutually supportive hierarchy of facts and concepts which are correlated as far as possible.

The approach followed to determine the consistency of the syllabus was to trace the effect on the rest of the syllabus when complete units were removed. It was found that for the syllabus of the final two years (Standards 9 and 10) only the sections on radioactivity, non-ideal gases and organic chemistry could be deleted en toto without affecting any part of the rest of the syllabus. The syllabus content thus forms a highly consistent structure.

4. COMPARISON OF THE TWO EVALUATIONS

4.1 General outcomes

Both evaluations expose serious shortcomings in the syllabus content. The major shortcomings are

- (a) too many unnecessary topics;
- (b) moderate to low interest value of the chemistry component;
- (c) degree of difficulty compared to other school subjects;
- (d) length of the syllabus;
- (e) insufficient provision for understanding of concepts and the related prerequisite knowledge, and for understanding of the investigative methods (significance);
- (f) lack of balance in scope and depth (balance);
- (g) lack of relevance to life in general and to the life of the pupil (relevance).

4.2 Agreement in evaluation results

The following comparison shows the relationship in the results of the two methods of evaluation:

| | |
|---|---|
| 1. Too many non-essential topics. Length of syllabuses. | Lack of <u>balance</u> in scope and depth |
| 2. Only interesting in parts. Physics more interesting than chemistry. | Application of criterion of <u>interest</u> favours physics. Content not <u>relevant</u> to everyday life. |
| 3. Difficult in comparison with other subjects. | Lack of <u>balance</u> . Not <u>relevant</u> . |

Finally, it should be pointed out that both evaluations do not only expose weaknesses, but also indicate possible remedies and improvements to the syllabus content.

REFERENCES AND NOTES

1. Provincial Administration of the Cape of Good Hope: Department of Education, Senior Secondary Course: Syllabus for Physical Science (Higher Grade) and (Standard Grade). (Cape Town: Cape Provincial Administration, Department of Education, 1973), pp. 2 - 5.
(Also see APPENDIX VI.)
2. See Chapter 1.
3. See Reference 1, pp. 6 et seq.; also APPENDIX VI.
4. Chemical Education Material Study, Chemistry - an experimental science. (San Francisco: W.H. Freeman, 1963), pp. 1 - 16.
5. From the reports of discussion groups at a refresher course in Physical Science, University of Stellenbosch, 1976. This was also often mentioned to the author in discussions with teachers during official inspection visits, 1976 - 1977.
6. Consult APPENDIX VI.
7. See Reference 1, p. 29 (Higher Grade) or p. 24 (Standard Grade).
8. Ibid., p. 3.
9. James, T. Robinson, The Nature of Science and Science Teaching. (Belmont, Calif.: Wadsworth Publishing Company, 1968), pp. 116 et. seq.

CHAPTER 14SYLLABUS ORGANIZATION AND TEACHING METHOD

1. SYLLABUS ORGANIZATION

1.1 Introductory

It is difficult to relate the curriculum element of "organization" in a meaningful manner to the published syllabus. The syllabus is basically a list of content topics and does not describe the organizational principles to be used by the teacher. The type of curriculum organization found in practice also depends on the sequence and presentation favoured by the textbook used as well as on the teacher's own planning.

Observation of the teachers in action, together with a scrutiny of their record books by the author has shown that a variety of different organizations are used in Standard 8, but that most teachers closely adhere to the published syllabus sequence in Standards 9 and 10.¹

It has thus been decided to use the organization of the syllabus as the basis of evaluation.

1.2 The prescribed syllabus organization

The following statements related to organization are given in the introduction to the syllabuses:²

1. The subject should be taught as a structure consisting of an orderly framework of concepts, laws and theories. The framework represents the scientific aspects of the subject and serves to unify technologically useful facts.
2. Physical Science should be taught as a coherent, unified subject; it should be developed as such in a logical fashion.
3. The factual content should always be presented in such a manner that the contextual unity of the subject is maintained throughout.

4. The syllabus is divided into three separate parts of which only the last two, for Standards 9 and 10, will be examined in the final examination.
5. The syllabus presents one logical sequence of presentation. There are others. Teachers are free to rearrange the subject matter WITHIN ANY ONE YEAR'S syllabus to suit their own sequence of presentation.

From these statements two major organizational principles emerge, viz.

- (a) logical structure, and
- (b) structural and contextual unity.

It is further clearly implied that the theory ("concepts, laws and theories") should form both the basis of the logical structure and the unifying element of the syllabus.

1.3 The hidden syllabus organization

In addition to the stated organizational prescriptions, the syllabus also contains hidden prescriptions due to the logical, sequential structure of the prescribed content. Although it is stated that "teachers are free to rearrange the subject matter within any one year's syllabus to suit their own sequence of presentation" the syllabus structure itself makes this extremely difficult.

It is thus possible to present the physics component in parallel with the chemistry component in Standard 8, but it is prescribed that the physics component in Standard 9 should precede the chemistry component in Standard 10.

The physics component in Standard 8 consists of four distinct and separate units (light, sound, heat and electricity) which may be rearranged to suit the development of the pupils, for practical reasons, etc. The chemistry component, however, forms a logical sequence which may be extremely difficult to rearrange.

With a few exceptions, such as nuclear reactions and organic chemistry, both the physics and chemistry components of Standards 9 and 10 have a similar logical sequence which forces the teacher to follow the organization prescribed by the syllabus. The parallel presentation of physics and chemistry would involve transferring material from Standard 9 to Standard 10, and vice versa, and this is specifically prohibited.

1.4 A criterion-based evaluation of the syllabus organization

The organization outlined in the previous paragraphs actually represents the status quo in most schools. As such it may be said to represent the curriculum organization generally employed and can thus be tested against the criteria developed in Chapter 8.

1.4.1 The criterion of systematic subject structure

The syllabus organization is a strictly logical one, representing the current and modern view of physics and chemistry as academic disciplines. In this sense the organization provides for a systematic subject structure.

Whether this logical structure is the most suitable for a school course may be questioned on various grounds (see Chapter 8, Section 2.4.1), since the criterion emphasises structure in the context of a school subject and not of an academic discipline.

1.4.2 The criterion of cumulative learning

This criterion implies the provision of opportunities for pupils to progressively increase their knowledge and understanding and to reinforce and apply previously acquired knowledge in order to extend and enrich their learning.

The strictly logical sequence of the syllabus, together with the provision that physics and chemistry may not be presented in a parallel sequence, makes it extremely difficult to provide for cumulative learning. The chemistry component, in particular, consists of a rapid succession of new concepts and principles to be mastered and understood in a limited period of time, resulting in a severe lack of provision for reinforcement and meaningful application.

The limited amount of spiralling introduced in chemistry (atomic structure, valency, periodic table, bonding, and acid-base reactions) is the only evidence of a conscious effort to provide for cumulative learning.

1.4.3 The criterion of developmental sequence

According to this criterion the content should be organized in a sequence which matches and is compatible with the psychological development of the pupil. This criterion requires, for instance, that the accepted conceptual structures of physics and chemistry be re-examined and redesigned in order to make them compatible with the pupils' intellectual level. The essential prerequisite knowledge and skills must be provided for and should be wellmastered before attempting to proceed to the next, more difficult and complex stage of learning. The syllabus organization can be faulted in many respects with regard to provision for a developmental sequence. Aspects of heat, such as internal energy and thermal energy, may be considered too difficult and abstract to be understood by 15 year old pupils. The organization of the chemistry component which requires "theory before facts" is another example of the complete disregard of the psychological principles of development of conceptual structures. To be compatible with the mental and intellectual development of the pupil the study of substances and their reactions (inorganic chemistry) should precede and not follow the theoretical concepts.

1.4.4 The criterion of integration

The subject Physical Science is, as its name implies, an integrated subject. In South Africa it has come to mean a combination of only two physical sciences, viz. physics and chemistry. Integration between these two components is effectively achieved by the logical, developmental sequence and by concentrating on physical rather than on descriptive chemistry. The latter procedure provides for a wide application of physical concepts in the study of chemistry. The integration has been so successful that the change from the "pure" physics to the "pure" chemistry component is natural and gradual - the one ends and the other starts in the study of the atom and its electronic structure.

The other aspect of integration, viz. the integration of the subject matter with other fields of study and everyday life, seems to be almost completely absent.

1.4.5 The criterion of methodological progression

This criterion provides for organizing the content in a manner and sequence which is in agreement with the accepted methodological progressions, e.g. to proceed from the concrete to the abstract, etc.

(a) From the known to the unknown:

This progression implies that knowledge of facts should precede the development of theories. In chemistry, for example, acid-base theory should be based upon and be illustrated with acids and bases familiar to the pupils. Without a previous study of substances and the different types of reactions (acid-base, oxidation-reduction, reversible, exothermic, endothermic, etc.) the theory cannot be made meaningful. Examples, applications and illustrations must be known in order to serve the purpose of illuminating the theory.

In terms of organization this means that the study of physical phenomena, chemical substances and reactions should be followed by theories and models evolved to explain and classify the variety of phenomena and reactions. This aspect is ignored in the syllabus structure.

(b) From the concrete to the abstract:

Not all physical realities are concrete, e.g. electromagnetic waves, being a disturbance in the electromagnetic field, can only be observed indirectly through observing their effects and by using the appropriate apparatus. Many other topics included in the syllabus may, however, be introduced and developed through concrete experience. The type of organization which provides for this approach will include appropriate experiments and investigations as part of and integrated with the content. The syllabus lists the "prescribed experiments and demonstrations" separately, although an effort has been made to place them next to the appropriate content sections.

- (c) From the particular to the general:

The comments made under (a) above, also apply to this methodological progression. In the syllabus general theory precedes the study - which in itself is extremely limited - of particular phenomena and reactions.

- (d) From the easy (simple) to the more difficult (complex):

This aspect was discussed in paragraph 1.4.3.

- (e) From the whole to the parts:

This aspect, too, is intimately related to the organization of the chemistry content. It has been remarked that "one must know at least some chemistry before one can even begin to understand chemical theories".³ Some knowledge of the wide field of chemical substances and reactions (the "whole") is essential before details about the separate theories and mechanisms (the "parts") can be understood.

1.4.6 The criterion of practicality

With a few minor exceptions this criterion is being met by the syllabus sequence and organization. The two main objections in this respect are the following:

- (a) The relationship between the length of the syllabus and the time available. (In the Cape Province an average of 200 school days is available per year. From this must be subtracted the time taken by an average of three examinations per year, i.e. approximately 30 - 40 school days. As a rule 6 or 7 35-minute periods per week are allocated to Physical Science.)
- (b) The fixed logical sequence of topics. In the coastal regions this means that experiments on electrostatics have to be carried out under conditions of high humidity during the rainy winter season.

1.5 Summary

The curriculum organization complies fully, or to a large extent, with the criteria of

- (a) systematic subject structure;
- (b) integration;
- (c) practicality.

The organization is severely lacking in respect of the criteria of

- (a) cumulative learning;
- (b) developmental sequence;
- (c) methodological progression.

2. TEACHING METHODS

2.1 General methods used by teachers

2.1.1 According to the questionnaire to teachers

Three major teaching methods, based on the personal observation of teaching practice in 48 Cape schools,⁴ were each subdivided into three variations. Teachers were requested to indicate which of these nine methods they used regularly ("as a rule") and which of these methods they considered to be the most suitable for the teaching of Physical Science.

| METHOD | Method used | | Method preferred | |
|--|-------------|-------|------------------|-------|
| | Number | % | Number | % |
| 1. <u>Lecture methods</u> | | | | |
| 1.1 Traditional lecture method according to textbook | 21 | 12,3 | 0 | 0,0 |
| 1.2 Traditional lecture method + overhead projector as aid | 7 | 4,1 | 0 | 0,0 |
| 1.3 Traditional lecture method + prescribed practical work | 34 | 19,9 | 10 | 5,8 |
| TOTAL (1) | 62 | 36,3 | 10 | 5,8 |
| 2. <u>Demonstration methods</u> | | | | |
| 2.1 Lesson <u>followed by</u> demonstration(s) | 13 | 7,6 | 5 | 2,9 |
| 2.2 Lesson <u>based on</u> demonstration(s) | 30 | 17,5 | 41 | 24,0 |
| 2.3 Lesson and demonstration <u>integrated</u> | 47 | 27,5 | 42 | 24,6 |
| TOTAL (2) | 90 | 52,6 | 88 | 51,5 |
| 3. <u>Activity methods</u> | | | | |
| 3.1 Lesson <u>followed by</u> pupil experiment(s) | 12 | 7,0 | 31 | 18,1 |
| 3.2 Lesson <u>based on</u> pupil experiment(s) | 2 | 1,2 | 23 | 13,5 |
| 3.3 <u>Self-discovery</u> from pupil experiment(s) | 5 | 2,9 | 19 | 11,1 |
| TOTAL (3) | 19 | 11,1 | 73 | 42,7 |
| TOTAL | 171 | 100,0 | 171 | 100,0 |

TABLE 14.1 COMPARISON OF TEACHING METHODS USED AND TEACHING METHODS PREFERRED BY TEACHERS

According to TABLE 14.1 most teachers avail themselves of demonstration methods (52,6%), followed by lecture methods (36,3%). Activity methods are used by only 11,1% of the teachers. Demonstration methods are also preferred as being the most suitable (51,5%), closely followed by activity methods (42,7%).

2.1.2 According to the observation schedule

Analysis of the 137 observation schedules completed for 48 teachers of Physical Science, yielded the results summarised in TABLE 14.2. Because of the overlap of some of the methods and the very approximate method of determining the frequency of use, the observed methods were grouped together under four main categories.⁵

| Method used for more than one half of the teaching time | Number | Percentage |
|---|--------|------------|
| 1. Lecture methods | 37 | 77,1 |
| 2. Discussion methods | 2 | 4,2 |
| 3. Demonstration methods | 6 | 12,5 |
| 4. Activity methods | 2 | 4,2 |
| Not classified* | 1 | 2,1 |

* Equal number of responses for lecture and demonstration methods.

TABLE 14.2 TEACHING METHODS USED ACCORDING TO CLASSROOM OBSERVATION

The fact that lecture methods were used by 77% of the teachers and demonstration methods by only 12,5% (as compared to 36% and 52,6% respectively according to the questionnaire), may be explained by the overlap of these two methods in practice and by the fact that methods 3.1 (lecture followed by practical work) and 2.1 (lesson followed by demonstration) did not appear in the observation schedule. The method of observation used would have included these two categories under lecture methods. If these "corrections" are made to the teachers' responses the position is as follows:

Lecture methods: 50,8%; demonstration methods: 45,0%;
activity methods: 4,1%.

| QUESTION | YES | | NO | |
|--|--------|------|--------|------|
| | Number | % | Number | % |
| 1. Does the school have a <u>laboratory</u> for Physical Science? | 167 | 97,7 | 4 | 2,3 |
| 2. Is the laboratory <u>available at all times</u> ? | 147 | 86,0 | 20 | 11,7 |
| 3. Do you have sufficient <u>apparatus for pupil experiments in small groups of 2 - 4 pupils</u> ? | 108 | 63,2 | 63 | 36,8 |
| 4. Do you have sufficient <u>apparatus for demonstrations</u> ? | 151 | 88,3 | 19 | 11,1 |
| 5. Does the length of the syllabus allow <u>sufficient time for practical work</u> ? | 56 | 32,7 | 114 | 66,7 |
| 6. Do your pupils carry out <u>practical work after school hours</u> ? | 22 | 12,9 | 149 | 87,1 |

(N = 171)

TABLE 14.4 AVAILABILITY OF LABORATORIES, APPARATUS AND TIME FOR PRACTICAL WORK

Most schools have a laboratory for physical science (97,7%) which is available at all times (86%). The provision of apparatus also seems to be reasonably satisfactory. The low frequency of activity methods may thus be ascribed to the lack of laboratory assistants and the length of the syllabus.

2.1.4 Teaching aids

Modern teaching methods are supported by the use of a variety of teaching aids. Some of these, like motion pictures, the overhead projector and models, have been adapted effectively for use in the teaching of the sciences. The position regarding the availability and effectiveness of the different aids is illustrated in TABLES 14.15, 14.16 and 14.17.

2.1.5 The textbook as a teaching-learning aid

The Cape Department of Education did not allow the inclusion of questions on specific textbooks. The information obtained from the questionnaires is consequently of a general and unspecific nature and should be interpreted with caution.

All the schools involved in the investigation use one or more of the available South African textbooks.⁶ Two schools also use overseas textbooks. Supplementary South African textbooks are used in 49 schools (28,7%) and supplementary overseas texts are used in 8 schools (4,7%). Supplementary or additional notes are supplied by 112 teachers (65,5%). The teachers' evaluation of the South African textbooks used, is summarised in TABLE 14.8.

| Aspect of textbook | Number | % |
|--|--------|------|
| 1. Complete coverage of syllabus | 166 | 97,1 |
| 2. Clarity of explanations | 149 | 87,1 |
| 3. Suitability of language for study by pupils | 151 | 88,3 |
| 4. Effectiveness of illustrations | 152 | 88,9 |
| 5. Usefulness of end-of-chapter questions | 166 | 97,1 |

(N = 171)

TABLE 14.8 TEACHERS' EVALUATION OF SOUTH AFRICAN TEXTBOOKS

This apparent satisfaction with the available textbooks should be interpreted in the light of the related information obtained from university lecturers and pupils.

Three textbooks generally used in South African schools were listed in the questionnaire to university lecturers. They were requested to evaluate these texts for the scientific correctness of the content. The following results were obtained:

| | Number of lecturers acquainted with the textbook (N = 50) | Scientifically correct: | |
|------------|--|----------------------------|----|
| | | YES | NO |
| Textbook 1 | 19 | 13 | 6 |
| Textbook 2 | 19 | 16 | 3 |
| Textbook 3 | 6 | 5 | 1 |

TABLE 14.9 LECTURERS' EVALUATION OF SCIENTIFIC CORRECTNESS OF TEXT-BOOKS

Thus on average very nearly 80% of those lecturers acquainted with the various textbooks are satisfied with the correctness of the content.

| Aspect of textbook | Number | % |
|---|--------|------|
| 1. Clarity of explanations | 805 | 66,0 |
| 2. Aid to understanding | 965 | 79,2 |
| 3. End-of-chapter questions as aids to understanding | 1 025 | 84,1 |
| 4. Additional notes supplied by teacher | 767 | 62,9 |
| 5. Prefer learning from notes rather than from textbook | 524 | 43,0 |

(N = 1 219)

TABLE 14.10 PUPILS' EVALUATION OF TEXTBOOKS AND TEACHERS' NOTES

The pupils' evaluation corresponds fairly well with that of the teachers, although there is a significant difference in opinion about the clarity of the explanations. Whether this is due to the quality of writing or the inherent difficulty and complexity of the material is not ascertainable from this study.

2.1.6 Pupils' evaluation of laboratory activities

Pupils' attitudes towards and evaluation of the educational value of demonstrations and pupil experiments were tested in order to gain a second perspective on the relative value of these two methods.

Their responses to the questions on these aspects are summarised in TABLE 14.11.

| Aspect of laboratory activities | YES | | NO | |
|--|--------|------|--------|------|
| | Number | % | Number | % |
| 1. Like to carry out practical work themselves | 1 093 | 89,7 | 79 | 6,5 |
| 2. Like demonstrations performed by the teachers | 1 099 | 90,2 | 53 | 4,3 |
| 3. Pupil experiments are aids to understanding | 1 106 | 90,7 | 63 | 5,2 |
| 4. Teachers demonstrations are aids to understanding | 1 038 | 85,2 | 69 | 5,7 |
| 5. Demonstrations are better aids to understanding than pupil experiments | 287 | 23,5 | 701 | 57,5 |
| 6. Demonstrations and pupil experiments are equally effective as aids to understanding | 610 | 50,0 | 404 | 33,1 |
| 7. Pupil experiments are better aids to understanding than teacher demonstrations* | 293 | 24,0 | - | - |

(N = 1 219)

* Indirectly obtained from the number of "NO" responses to both questions 5 and 6.

TABLE 14.11 PUPILS' ATTITUDES TOWARDS AND EVALUATION OF PUPIL EXPERIMENTS AND TEACHER DEMONSTRATIONS

The controversy about demonstrations versus pupil experiments is not resolved by the pupils' responses to the questions. No significant difference between the popularity and effectiveness of these two methods was obtained and it would seem that both these methods should be used in a balanced educational programme.

2.2 Summary

Since the syllabus neither prescribes nor recommends any specific methodology, and because questions pertaining to the methodologies of the specific textbooks were ruled out by the Department of Education, it would serve no useful purpose to try and apply the principles developed in Chapter 9 to the variety of methods observed in the different schools. The general impression gained, both from the questionnaire and the observation of teaching, is that the lecture method, supplemented by demonstrations and the minimum of prescribed pupil experiments, predominates.

The major findings may be summarised as follows:

1. General methodological approach used:
 - (a) Lecture type, supplemented by demonstrations and some pupil experiments: > 60%
 - (b) Fully integrated demonstration methods: < 30%
 - (c) Activity and discussion methods: < 10%
2. Factors affecting the teaching method:
 - (a) External examination (72,5%).
 - (b) Length of the syllabus (60,8%).
 - (c) Methodology of textbook (60,2%).
3. Factors affecting laboratory activities:
 - (a) Laboratories: 97,7% have laboratories of which 88% are available at any time.
 - (b) Apparatus: 88,3% have sufficient demonstration apparatus; 63,2% have sufficient apparatus for small group experiments.
 - (c) Length of syllabus does not allow sufficient time for practical work: 66,7%.

4. Teaching aids:

- (a) Main aids available:
- | | |
|---------------------------|-------|
| (i) Demonstration models: | 98,8% |
| (ii) Overhead projector: | 98,2% |
| (iii) Ciné projector: | 83,0% |
| (iv) Slide projector: | 76,0% |
- (b) Effectiveness of aids according to teachers:
- | | |
|-------------------------|-------|
| (i) Overhead projector: | 83,0% |
| (ii) Ciné projector: | 42,7% |
- (c) Effectiveness of aids according to pupils:
- | | |
|---------------------------|-------|
| (i) Demonstration models: | 93,8% |
| (ii) Ciné projector: | 85,6% |
| (iii) Overhead projector: | 64,5% |

5. The textbook as aid:

- (a) Contents scientifically correct: ca. 80%
- (b) Covers syllabus completely: 97,1%
- (c) Clarity of explanations:
- | | |
|---------------|-------|
| (i) Teachers: | 87,1% |
| (ii) Pupils: | 66,0% |
- (d) Suitability of language: 88,3%
- (e) Effectiveness of illustrations: 88,9%
- (f) Usefulness of end-of-chapter questions:
- | | |
|---------------|-------|
| (i) Teachers: | 97,1% |
| (ii) Pupils: | 84,1% |
- (g) Aid to understanding (pupils): 79,2%

6. Pupil experiments and demonstrations:

- No significant difference as to popularity (ca. 90%)
and effectiveness as aids to understanding (ca. 74%).

The evaluation results indicate that in designing the methodology for a curriculum for Physical Science, the curriculum designer should take into consideration

- (a) a balance between pupil experiments and demonstrations;
- (b) the special effectiveness of demonstration models and films as aids to understanding;
- (c) the important role of the textbook;
- (d) the length of the curriculum in order to allow sufficient time for laboratory activities.

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2. Provincial Administration of the Cape of Good Hope: Department of Education, Senior Secondary Course: Syllabus for Physical Science (Higher Grade) and (Standard Grade). (Cape Town: Cape Education Department, 1973), pp. 2 - 5.

Also see: APPENDIX VI.
3. Comment by chemistry lecturer, University of Cape Town, on Questionnaire to University Lecturers. See APPENDIX V.
4. See Chapter 11, Section 3.4.
5. See APPENDIX VII.
6. See BIBLIOGRAPHY.

CHAPTER 15ASPECTS OF SYLLABUS EVALUATION

1. THE CRITERION-INDEPENDENT EVALUATION

1.1 Introductory

Very little curriculum evaluation has been done in South Africa in the immediate past. Syllabus changes have usually resulted from pressures from universities and from an awareness of certain changes and trends in overseas countries, rather than from any evaluation of existing syllabuses. The studies of Muller¹, Schutte², Malan³ and Helm⁴, which evaluated various aspects of the teaching of Physical Science, were concerned with syllabuses which are not applicable to the present system of differentiated education. Some aspects of Helm's work, which are related to school physics in general, and of the work of Fox⁵ on the various content items of the chemistry component of the syllabus, are possible exceptions.

There is, however, no academic or official evaluation of the syllabus available at present which can be used to test the effectiveness and validity of the criteria for evaluation which were developed in Chapter 10. The comparative evaluation of the final element of the curriculum is thus of necessity limited to the aspect of pupil assessment.

1.2 Syllabus aims and pupil assessment

The following ~~five~~⁶ main categories of official aims are stated in the syllabuses:

1. Aims pertaining to the acquisition of knowledge;
2. aims pertaining to physics and chemistry as disciplines;
3. aims pertaining to application in technology and industry;
4. aims pertaining to laboratory procedures and skills;
5. general educational aims (citizenship and preparation for continued study in the sciences).

The number of marks allocated to questions which test each of the aims pertaining to knowledge, application in technology and industry, and laboratory procedures and skills, were determined by means of question analysis of the papers set in the final external examinations of 1976 and 1977 (Cape Education Department). The data are summarised in TABLE 15.1.

| SYLLABUS GRADE | PAPER | SYLLABUS AIMS | | | | | |
|----------------------|-------|---------------|------|-------------|------|------------|-----|
| | | Knowledge | | Application | | Laboratory | |
| | | Marks | % | Marks | % | Marks | % |
| HIGHER GRADE (400) | 1976 | 352 | 88,0 | 41 | 10,3 | 7 | 1,8 |
| | 1977 | 344 | 86,0 | 36 | 9,0 | 20 | 5,0 |
| | TOTAL | 696 | 87,0 | 77 | 9,6 | 27 | 3,4 |
| STANDARD GRADE (300) | 1976 | 277 | 92,3 | 5 | 1,7 | 18 | 6,0 |
| | 1977 | 252 | 84,0 | 23 | 7,7 | 25 | 8,3 |
| | TOTAL | 529 | 88,2 | 28 | 4,7 | 43 | 7,2 |
| TOTAL ALL GRADES | | 1 225 | 87,5 | 105 | 7,5 | 70 | 5,0 |

TABLE 15.1 MARKS ALLOCATED TO THE TESTING OF DIFFERENT CATEGORIES OF AIMS IN THE FINAL EXAMINATION: 1976 AND 1977

The assessment of aims pertaining to physics and chemistry as disciplines and aims of a general educational nature, cannot be determined by such an analysis. If the actual examination papers⁷ are scrutinised, it is apparent that the testing of formal, academically accepted theory and hypothetical applications, predominate. It would thus be reasonable to assume that the pupil assessment provides for the attainment of aims related to the disciplinary nature of physics and chemistry.

The available evidence⁸ seems to indicate that the syllabus does not effectively prepare pupils for tertiary studies in the sciences and that the final examination is a fairly inaccurate predictor of success in continued studies. From this evidence, which is confirmed by the responses and remarks of university lecturers (TABLE 15.2) one may conclude that the evaluation systems fails in the assessment of the attainment of this aim.

| ABILITY | PHYSICS (N = 28) | | CHEMISTRY (N = 22) | | TOTAL (N = 50) | |
|--|---------------------|------|-----------------------|-------|-------------------|------|
| | Number | % | Number | % | Number | % |
| 1. <u>General:</u> Preparation of pupils compared to the past: | | | | | | |
| (a) Better | 6 | 21,4 | 3 | 13,6 | 9 | 18,0 |
| (b) Poorer | 1 | 3,6 | 8 | 36,4 | 9 | 18,0 |
| (c) No difference | 18 | 64,3 | 7 | 31,8 | 25 | 50,0 |
| (d) Cannot decide | 3 | 10,7 | 4 | 18,2 | 7 | 14,0 |
| 2. <u>Specific:</u> | | | | | | |
| 2.1 Able to use laboratory equipment: | | | | | | |
| (a) YES | 6 | 21,4 | 1 | 4,5 | 7 | 14,0 |
| (b) NO | 21 | 75,0 | 20 | 90,9 | 41 | 82,0 |
| (c) UNCERTAIN | 1 | 3,6 | 1 | 4,5 | 2 | 4,0 |
| 2.2 Able to produce clear reports: | | | | | | |
| (a) YES | 1 | 3,6 | 0 | 0,0 | 1 | 2,0 |
| (b) NO | 27 | 96,4 | 22 | 100,0 | 49 | 98,0 |
| 2.3 Able to interpret quantitative data | | | | | | |
| (a) YES | 7 | 25,0 | 2 | 9,1 | 9 | 18,0 |
| (b) NO | 19 | 67,9 | 14 | 63,6 | 33 | 66,0 |
| (c) UNCERTAIN | 2 | 7,1 | 6 | 27,3 | 8 | 16,0 |

TABLE 15.2 LECTURERS' EVALUATION OF CERTAIN ABILITIES OF FIRST YEAR STUDENTS

University lecturers identify the following main areas of chemistry and physics in which the preparation of first year students is severely lacking (i.e. more than 20% of the responses):

1.2.1 Physics (N = 28):

1. Lack of (mainly manipulative) mathematical skills (19; 67,9%);
2. lack of problem-solving ability (10; 35,7%);
3. lack of ability to think/reason logically (7; 25,0%);
4. lack in language ability (assignments; answers to test questions; transferring data into words) (6; 21,4%);
5. lack of laboratory skills and lack of knowledge of laboratory procedures (6; 21,4%).

1.2.2 Chemistry (N = 22):

1. Lack of knowledge of simple and common chemicals, formulae and writing and interpreting chemical equations (18; 81,8%);
2. lack of knowledge of and ability in handling stoichiometric aspects (12; 54,5%);
3. lack of laboratory skills and lack of knowledge of laboratory procedures (8; 36,4%).

The majority of lecturers in chemistry also mentioned "lack of motivation", "boredom" and "lack of interest" as a result of covering the same theoretical concepts at university as at school.

The lack of manipulative ability in mathematics and the inability to handle stoichiometric relationships (which requires manipulation of ratios and proportions) reflect not only on the syllabus for Physical Science but also on the teaching of mathematics. Likewise, the deficiency in the ability to communicate in writing, reflects adversely on the teaching of this language skill.

1.3 Categories of knowledge assessed

A sample of four examination papers⁹ was analysed to determine the main categories of knowledge usually assessed in the final examinations. The categories used in the analysis, were

- A. Knowledge (recall of information);
- B. comprehension (application of principles to familiar situations);
- C. application (application of principles to unfamiliar situations);
- D. higher abilities (problem situations; design of experiments; critical appraisal and interpretation of data).

A full explanation of these four categories was given in Chapter 11, Section 3.5.2.

The results of the analysis are tabulated in TABLE 15.3. In order to limit the effects of a personal interpretation, the classification of questions was also carried out by three experienced teachers. Two of them are experienced sub-examiners and the other also served as an examiner for the physics component of Physical Science. The results contained in TABLE 15.3 are the averages of the four independent analyses.

| SYLLABUS GRADE | PAPER | CATEGORIES OF KNOWLEDGE | | | | | | | |
|----------------------------|-------|-------------------------|------|--------------------|------|------------------|------|---------------------|-----|
| | | KNOWLEDGE | | COMPRE- HENSION | | APPLI- CATION | | HIGHER ABILITIES | |
| | | Marks | % | Marks | % | Marks | % | Marks | % |
| HIGHER GRADE (540) | 1976 | 118 | 21,9 | 278 | 51,5 | 140 | 25,9 | 4 | 0,7 |
| | 1977 | 102 | 18,9 | 278 | 51,5 | 123 | 22,8 | 37 | 6,9 |
| | TOTAL | 220 | 20,4 | 556 | 51,5 | 263 | 24,4 | 41 | 3,8 |
| STANDARD GRADE (400) | 1976 | 119 | 29,8 | 224 | 56,0 | 57 | 14,3 | 0 | 0,0 |
| | 1977 | 123 | 30,8 | 212 | 53,0 | 65 | 16,3 | 0 | 0,0 |
| | TOTAL | 242 | 30,3 | 436 | 54,5 | 122 | 15,3 | 0 | 0,0 |

TABLE 15.3 MARKS ALLOCATED TO DIFFERENT CATEGORIES OF KNOWLEDGE IN THE FINAL EXAMINATION: 1976 AND 1977

Allowing for errors of interpretation, the general pattern of examining seems to be as follows:

| | <u>Higher Grade</u> | <u>Standard Grade</u> |
|----------------------|---------------------|-----------------------|
| A. Knowledge: | 20% | 30% |
| B. Comprehension: | 50% | 55% |
| C. Application: | 25% | 15% |
| D. Higher abilities: | 5% | 0% |

If the final examination is to reflect the aims pertaining to the disciplinary structure of physics and chemistry, and the preparation of pupils for continuing study in the sciences, one would expect to find a relatively higher proportion of the marks allocated to application and the higher abilities.

Apart from the greater emphasis on knowledge and comprehension (of approximately 15%) in the question papers for the Standard Grade, the nature of the questions set for this grade is also much simpler and more direct. It is obvious that the examination forms the major technique for differentiating between the two levels of education.

1.4 Aspects of the examination questions and papers

Complaints by teachers on the length of the examination papers are common,¹⁰ and so are the arguments for and against objective type and essay type examination questions.¹¹ In this study a limited number of questions on these aspects was put to pupils in an effort to obtain the views of the "consumer" on these issues. Their responses to these questions are summarised in TABLE 15.4.

The results obtained confirm that the teachers' objections to too long examination papers are justified. More than three quarters of the pupils state that insufficient time is allowed for completion of the papers.

Although there is no clear preference for the longer type of examination question over the objective type test item (46,7% : 42,6%), and both question types are considered to test knowledge of facts properly, there is considerable doubt in pupils' minds about the effectiveness of the objective test items to test understanding. This doubt is further emphasised by the large percentage (20%) of pupils who are uncertain about this item.

| ASPECT OF EXAMINATIONS | YES | | NO | | UNCERTAIN | |
|---|--------|------|--------|------|-----------|------|
| | Number | % | Number | % | Number | % |
| 1. Sufficient time allowed | 227 | 18,6 | 933 | 76,5 | 59 | 4,8 |
| 2. Prefer longer type questions to objective test items | 569 | 46,7 | 519 | 42,6 | 131 | 10,7 |
| 3. Longer type of question tests facts properly | 796 | 65,3 | 280 | 23,0 | 143 | 11,7 |
| 4. Objective items test facts properly | 780 | 64,0 | 274 | 22,5 | 165 | 13,5 |
| 5. Longer type of question tests understanding properly | 1 021 | 83,8 | 130 | 10,7 | 68 | 5,6 |
| 6. Objective items test understanding properly | 498 | 40,9 | 476 | 39,0 | 245 | 20,1 |

(N = 1 219)

TABLE 15.4 PUPILS' OPINIONS ON THE LENGTH OF EXAMINATION PAPERS AND DIFFERENT TYPES OF QUESTIONS

Answers to examination questions in the categories "application" and "higher abilities" require sufficient time for the analysis of problems, the selection of the appropriate principles and the application of these principles or of the correct problem-solving procedures.

1.5 The use of pupil assessment in curriculum evaluation

In the United States and Great Britain the tendency is to associate the word evaluation with curriculum evaluation, reserving the words assessment, testing and examination for activities associated with the attainment measurement of the individual.¹² The former - curriculum evaluation - can be less precise, but the latter, where the individual's future may be at stake, requires more precise and accurate instruments and procedures. "One should however recombine the two concepts. Examinations ... undoubtedly act as a kind of curriculum evaluation. The

of problem situations, the design of experiments, and the critical appraisal and interpretation of data, is limited to the Higher Grade paper of which it comprises less than 5% of the total number of marks.

5. Insufficient time is allowed for the completion of examination papers. Sufficient time is essential for answering questions testing application and the higher abilities.
6. The analysis of the answers to the questions on the different syllabus topics and the various types of knowledge tested by the examinations, can provide valuable evaluation feedback for curriculum improvement. This feedback has been completely neglected in national syllabus revision in South Africa.
7. The examination - as a component of curriculum evaluation - seems to be consistent with the syllabus aims pertaining to the acquisition of knowledge and to physics and chemistry as academic disciplines. The assessment is not consistent with the aims pertaining to application in technology and industry, laboratory skills and procedures and the general educational aims such as citizenship and preparation for continued study in the sciences.

2. THE CRITERION-BASED EVALUATION

2.1 Introductory

In the application of the criteria for curriculum evaluation to the final examinations, it must be kept in mind that such application is limited to pupil assessment as a component of curriculum evaluation. The curriculum-based evaluation should thus not be interpreted as an assessment of the validity, objectivity, reliability, suitability and structure of the examinations.

2.2 The criterion of consistency with aims

The syllabus for Physical Science provides for five categories of aims, namely, aims pertaining to

1. the acquisition of knowledge;
2. physics and chemistry as academic disciplines;
3. application of principles in industry and technology;
4. laboratory procedures and skills;
5. general educational aims (citizenship and preparation for tertiary studies in the physical sciences).

The final examination should provide evidence of the attainment of the aims by pupils. The general educational aims listed in the syllabus introduction, may be excluded as being long-term aims, the attainment of which may not be directly measurable by an examination paper.

When this criterion is applied to the examination one finds that the assessment is consistent with aims (1) and (2) above, but not with aims (3) and (4).

2.3 The criterion of comprehensiveness

According to this criterion the evaluation must be comprehensive in terms of its breadth of coverage of all aspects of the curriculum as well as in terms of involving everyone concerned with the design and implementation of the curriculum.

Examinations, being primarily concerned with pupil assessment, form only one aspect of the complete evaluation process. They can, however, provide information on the attainment and attainability of curriculum objectives, the effectiveness and suitability of methods and teaching-learning activities (experiments, investigations and demonstrations), the curriculum organization, and the assessment procedures themselves. The comparison of pupils' scores in physics and chemistry may, for example, provide information on the effectiveness of sequential teaching of these two components.

As far as could be ascertained from official sources the examinations have up to the present only been used to determine whether pupils pass or fail in the subject, at what level the pass mark has been obtained (indicated by a series of symbols A, B, C, D, E) and as a selection procedure for university entrance. The examination results also form a component of teacher evaluation for the purpose of assessing teachers' promotability.

One may thus conclude that the assessment aspect of curriculum evaluation is not being utilised to its fullest and thus does not comply with the criterion of comprehensiveness in terms of breadth of coverage.

Also, since all the information which may be gained from the examinations, is not fed back to the curriculum designers and teachers, the examination also fails to involve all those persons and bodies concerned with curriculum improvement and implementation.

2.4 The criterion of diagnostic value

In order to be able to identify possible strengths and weaknesses of a curriculum, and to determine the possible reasons for such strengths and weaknesses, detailed feedback is essential. The lack of feedback from the final examinations virtually removes the possibility of meaningful diagnosis.

2.5 The criterion of maximum rigour

The poor reliability of the matriculation examination and its low validity as a predictor of success at university have been discussed at some length by Malherbe.¹⁴ In the context of curriculum evaluation this criterion cannot be applied to the final examination in isolation from other evaluation procedures. Since such evaluations are not available at present¹⁵ this criterion must, for the time being, be excluded from the criterion-based evaluation.

2.6 The criterion of unity

In the application of this criterion, too, the fact that pupil assessment forms but one aspect of the complete evaluation process, must be realised. It would thus be extremely difficult to obtain unity, in the sense of the relationships and interactions among the different curriculum elements, from the results provided by an examination. Within any single component of the total evaluation process, however, the maximum amount of unity should always be strived for. In the present situation in which the final examination is limited to serving as a yardstick for measuring pupil success in the written examination as such, no such unity exists.

2.7 The criterion of relatedness to practical teaching

Periodic term and final examinations (promotion examinations) form an integral part of the South African school education system. Both pupils and teachers are used to the system and the majority accept the status quo without question, although teachers are constantly aware

of the pressure of a final, external examination. In the context of the South African school system examinations are accepted as being part of the practical teaching situation and pupil assessment thus meets the requirement imposed by this criterion.

3. COMPARISON OF THE TWO EVALUATIONS

The results of the two types of evaluation may be compared as follows:

| | |
|---|--|
| 1. The examination concentrates on the attainment of the knowledge aim, both in the number and type of questions. | 1.(a) Partially consistent with the syllabus aims. (b) Lack of comprehensiveness. (c) Lack of unity. |
| 2. No feedback provided to curriculum designers. | 2. Lack of diagnostic value. |
| 3. Failure to assess the essential knowledge and abilities required for continued study, particularly in chemistry. | 3. Lacking in aspects of rigour (reliability and validity)? |

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6. See Chapter 12, Section 1.2.
7. APPENDIX VIII.
8. E.G. Malherbe, "The reliability and validity of the Matriculation examination", A.N. Boyce and B.W. Rose (eds.), Evaluation in Education. (Cape Town: Maskew Miller Ltd., 1975), pp. 207 - 210.

This is confirmed by the responses and remarks of the university lecturers on the questionnaire completed for this study.
9. APPENDIX VIII.
10. Based on complaints by science teacher study groups and individual teachers regarding examination papers. Information provided by the Cape Education Department.
11. A variety of publications and articles on this topic is available. In the South African context the reader is referred to Boyce and Rose (eds.), op. cit., ref. 8 above.

12. Jack Wrigley, "Approaches to assessment in secondary education and the consequences for higher education", Boyce and Rose (eds.), op. cit., p. 10.
13. Ibid., p. 10.
14. Malherbe, op. cit.
15. An investigation on a national scale into the teaching of Physical Science in South African secondary schools was launched in 1977 by the Human Sciences Research Council. The results of this investigation were not available at the time of writing.

CHAPTER 16CONCLUSIONS AND RECOMMENDATIONS

1. GENERAL CONCLUSIONS

1.1 Curriculum studies as an aspect of the methodology of education

1.1.1 The term "curriculum"

The definition of curriculum which is used in this study and is generally accepted in British and American educational publications, is not yet universally accepted. The increasing acceptance of this interpretation of the term is, however, evident from the more recent publications from both West and East European countries.¹ In South Africa the term "syllabus" ("sillabus" and "leerplan") is still being used by some faculties of Education as more or less synonymous with the current interpretation of curriculum. The fairly world-wide dissemination of the modern interpretation of the term "curriculum" may be largely due to the increasing number and frequency of international conferences and symposia on curriculum development. Bodies like UNESCO and The British Council are especially active in this field. The adherence of some South African universities to the out-moded terminology may be the result of the current political isolation and the termination of South Africa's membership of UNESCO.

1.1.2 Curriculum study as a separate sub-discipline of Education

During the course of this study it became increasingly clear that much of the diversity and controversy in the field of curriculum studies may be ascribed to the fact that curriculum study has developed into a separate, independent field of study and research. In doing so a multitude of "approaches" and "rationales", not necessarily based on or derived from educational principles, were employed as the bases for curriculum design, and the study of the curriculum

became increasingly divorced from the field of methodology of education. The implications of this trend were discussed in Chapters 2 and 9 and it was concluded there that this process of separating curriculum studies from the sub-discipline of methodology of education may be one of the primary reasons for the limited success or failure of some modern curriculum innovations.

1.2 Curriculum theory

1.2.1 The need for a unified curriculum theory

Strassenburg² has shown convincingly that the design and development of new curricula are usually not based on evidence obtained from proper evaluation but is often the result of the initiative and influence of outstanding individuals, university faculties of education and teachers' associations. In this process "general feelings of dissatisfaction", personal points of view and theories supported by certain schools of Education form the bases for what is grandiosely termed "curriculum innovation". As examples of the specific approaches which are often accepted with unshakeable conviction by their supporters, the behavioural objectives movement of Skinner and Mager, Bloom's taxonomy of educational objectives, the theories of learning and development of Piaget and Gagné, and Bruner's revival of Armstrong's heurism in the guise of enquiry-discovery methods may be mentioned.

Trotter³ labels this situation a "muddle of contrasting theories".

He says:

A specific theory or approach is necessary if a teacher is to do more than impart information on a hit-or-miss basis, but the superimposition of theories, sub-theories, and neo-theories on older theories, leads to a muddled education system. It is this muddle that is at the root of much criticism levelled at the education system.

In addition, two major models for curriculum design - the objectives model and the encounter model - gradually developed side by side. Each of these models collected its own share of adherents whose support very often depended on personal preference rather than on reasoned choice.

The need for a "specific theory or approach"⁴ - a theoretical model for curriculum design - which is independent of personal preferences for specific theories and philosophies, is apparent. If possible, such a model should combine the advantages, and aspects which have proved their value in the practical teaching situation, of both the encounter and objectives models.

1.2.2 The feasibility of a model for curriculum design

A number of models for curriculum design exist (Chapter 3). These models are not universally accepted and are usually based on either the encounter or objectives approach. Some are too theoretically abstract to serve as practical guides for curriculum construction, while others are limited to certain levels of education and instruction. One of the major deficiencies of these models is that they do not provide criteria for making decisions about the different components or elements of the curriculum.

From the analyses conducted on the structures of the different models (Chapters 3 and 4) it was concluded that the design of a unified, universal model and criteria for curriculum construction may be feasible.

2. CONCLUSIONS IN RESPECT OF THE MODEL AND CRITERIA FOR CURRICULUM DESIGN

2.1 The curriculum elements

Although it has not been possible to design and test a curriculum based on the model and criteria, all the curricula analysed,⁵ as well as the syllabus eventually used in the evaluation process,⁶ "fit" the proposed model or, more accurately, the model, being unified and universal, can accommodate all these curricula. The criteria, however, may be debatable on various grounds and should be subjected to thorough and complete testing. Unfortunately a complete evaluation was impossible under the limitations imposed

upon the present investigation (Chapter 11) and testing had to be limited to an initial feasibility study based on comparative evaluation of selected elements of the model.

The comparative evaluation consisted of two completely different procedures, namely, (a) a criterion-independent evaluation based on questionnaires to pupils, teachers and university lecturers, and (b) the application of the criteria to the curriculum elements aims, content, and evaluation.

The technique of comparative evaluation could not be applied meaningfully to the curriculum elements organization and method. The criteria developed for organization were applied to the prescribed syllabus organization in order to determine any deficiencies according to the criteria. These findings could not be controlled against any criterion-independent data. The many individual varieties of teaching methods made it not feasible to apply the criteria to each method or category of methods. The evaluation carried out by means of the questionnaires and the observation of classroom practice, did, however, provide a picture of the status quo regarding teaching methods as well as an indication of factors which should be considered in designing teaching methods and teaching-learning activities for a curriculum for Physical Science.

2.2 The criteria for curriculum aims

- 2.2.1 Both the criterion-independent and criterion-based evaluations revealed a number of deficiencies in the official syllabus aims.
- 2.2.2 The two evaluations agreed in identifying deficiencies in the areas of
- (a) validity;
 - (b) precision;
 - (c) relevance.
- 2.2.3 There was disagreement on the comprehensiveness of the aims. This difference may, however, be due to the formulation used in the questionnaire and the resulting different interpretation of this term by

teachers. The fact that it was found that the syllabus aims do not differentiate between the Higher and Standard Grades is a clear indication of a lack of comprehensiveness which agrees with the criterion-based evaluation.

2.2.4 The criteria of convergence, appropriateness and flexibility had no direct counterparts in the criterion-independent evaluation. The teachers' interpretation of comprehensiveness agreed broadly with the formulation of the criterion of flexibility. If this interpretation is accepted, the two evaluations also agreed on the criterion of flexibility.

2.2.5 Conclusion

The agreement in the results obtained from the two evaluations in those areas involving similar or common aspects of curriculum aims, is highly satisfactory.

2.3 The criteria for the selection of content

2.3.1 Complete agreement was obtained with respect to

- (a) balance;
- (b) interest;
- (c) relevance.

2.3.2 The criterion of significance had no direct counterpart in the questionnaires. The remarks and comments offered by the university lecturers supported the criterion-based finding that the syllabus content lacks significance.

2.3.3 The criteria of validity and consistency had no comparable counterparts in the criterion-independent evaluation.

2.3.4 Conclusion

The evaluation of common factors regarding syllabus content yields virtually complete agreement.

2.4 The criteria for curriculum evaluation

2.4.1 The comparative evaluation had to be limited to the pupil assessment (examination) component of complete evaluation.

2.4.2 The evaluations agreed fully or to a large extent on

- (a) consistency;
- (b) comprehensiveness;
- (c) unity;
- (d) diagnostic value;
- (e) rigour.

2.4.3 The criterion of relatedness to practical teaching had no direct, comparable counterpart in the criterion-independent evaluation.

2.4.4 Conclusion

A remarkably high degree of agreement on all common aspects of pupil assessment as a component of curriculum evaluation indicates that the criteria are valid and practically applicable.

2.5 The viability of the model and criteria

2.5.1 Although the comparative evaluation had to be limited to only three elements of the curriculum model, the highly satisfactory agreement obtained indicates that the model and its criteria offer a viable theoretical structure for curriculum design in the physical sciences.

2.5.2 The exercise also showed that the criteria can be applied effectively in a practical evaluation process and it is suggested that they would thus also be practically applicable in the design process.

2.5.3 In applying the criteria it was found that it may be possible to misinterpret some of the criteria, or to interpret them in a sense which was not originally intended. This suggests that the formulation of each criterion should be accompanied by a full explanation of the criterion and its application.

- 2.5.4 The general formulation of the criteria suggests that the model may be extended to other subjects as well.

3. CONCLUSIONS IN RESPECT OF INCIDENTAL FINDINGS

3.1 The Cape Education Department's syllabus for Physical Science

The selection of the syllabus of the Cape Education Department for Physical Science for evaluation was based on the author's intimate connection with and experience of the teaching of Physical Science in this province. This connection, as Inspector of Education in the sciences, made it possible to observe the teaching methods generally employed and to obtain direct evidence of the problems and objections of teachers regarding the syllabus for Physical Science.

In addition to the information on the feasibility of the curriculum model and its accompanying criteria, the evaluations also produced a number of important findings directly related to the Cape syllabus for Physical Science. Since this syllabus is almost identical to the syllabuses of the other examining bodies, these findings are also applicable on a national level.

3.1.1 The syllabus aims

1. Syllabus aims and objectives can be of great assistance to teachers in interpreting the content, planning the work and evaluating the outcomes of their teaching. The official syllabus aims fail in these respects.
2. Differentiation between the two syllabus grades is achieved by the omission of topics for the Standard Grade and by differentiated examinations. The official syllabus aims for both grades are, however, identical. Separate and different aims, giving clear guidance to teachers and examiners, are essential for effective differentiation.

3. The syllabus aims should be attainable. Official aims pertaining to citizenship, application of principles in technology and industry, and laboratory activities, should be sufficiently provided for in the syllabus content. Without the appropriate content to serve as the medium for attaining these objectives they are simply superfluous statements.
4. No mention is made regarding aims pertaining to pupil interest and the development of attitudes. Without provision for the development of interest in science and of positive attitudes towards science and its role in human affairs, Physical Science has only limited value for the general education of youth.

3.1.2 The syllabus content

1. The syllabus contains a large number of superfluous and extraneous topics which are not essential for an introductory study of physics and chemistry nor for preparing students for further study in these subjects.
2. The evaluation provided an indication of the units and topics which, according to teachers and university lecturers, could serve as the essential core of a revised or new syllabus.
3. Those topics which include a large number of pupil experiments and teacher demonstrations were rated by teachers as having a high interest value. This clearly indicates that the aims related to laboratory activities and pupil interest may both be attained by selecting content having an extensive and varied practical component.
4. In contrast to teachers, the majority of pupils do not find Physical Science more difficult than the other school subjects. Both groups, however, judge the chemistry component to be more difficult than the physics component. The difficulty of chemistry may be the result of the inclusion of too many abstract, theoretical concepts.

3.1.3 The syllabus organization

1. The rigid, logical structure based on the accepted views of physics and chemistry as academic disciplines makes rearrangement of the material virtually impossible.
2. The organization provides for a fairly rapid succession of concepts of approximately equal levels of difficulty and complexity. This structure does not provide for the progressive increase of knowledge and understanding, nor for sufficient opportunities for repetition, practice, application and mastery.
3. The division into physics and chemistry, and the prescription that physics must be taught in the Standard 9 year and chemistry in the Standard 10 year only allows a limited period of time for the provision of opportunities to repeat, reinforce, apply and master the chemistry content.
4. The organization of the chemistry content requires that principles and theories first be mastered and then applied to different reactions. According to university lecturers this order is "putting the cart before the horse".⁷ According to them a reasonable knowledge of chemical substances, their formulae and reactions, is essential before the theory can be taught in a meaningful way. This organization implies the inclusion of a unit or units devoted to the study of inorganic chemistry.
5. Topics which are too difficult or abstract are included in the early part of the syllabus (Standard 8). Among these are: aspects of heat; the mole concept; aspects of atomic structure and chemical bonding.

3.1.4 Teaching methods

Although the syllabus does not prescribe or recommend the methods to be used in teaching the various units and topics, the following findings should be taken into consideration in the choice of methods and the design of teaching-learning activities:

1. According to pupils both pupil experiments and teacher demonstrations are equally popular and effective. This indicates that the syllabus should provide for a balanced programme of both these activities and that the teaching method should not be exclusively based on one or the other.
2. Demonstration models and ciné films are specially effective as teaching aids. The production of models and films based directly on the syllabus content, should be seriously considered.
3. The textbook seems to play an extremely important role in the teaching and understanding of the subject. Good textbooks are therefore essential teaching-learning aids.
4. In order to provide for the effective application of activity and discussion methods, and for the carrying out of a sufficient number of pupil experiments and teacher demonstrations, the syllabus should not be too long. According to teachers and pupils, the present syllabus contains too much material.

3.2 The role of examinations in curriculum evaluation

Examinations can be an important component of curriculum evaluation. This important source of data is not utilised at present. For the purposes of curriculum evaluation the following aspects of pupil assessment, which are lacking in the existing system, should be considered:

1. The examination questions should test attainment in all the measurable objectives and not concentrate on the acquisition of knowledge only. At the same time it must be reiterated that knowledge is essential for understanding, for the development of attitudes, and for participating in meaningful and fruitful discussion on the issues pertaining to science.
2. A question analysis should be conducted on a representative sample of the answer papers of each annual examination in order to diagnose problems and weaknesses.
3. The data obtained from the analyses should be fed back regularly to curriculum designers and teachers.

4. RECOMMENDATIONS

4.1 The model and criteria

4.1.1 It is recommended that further research be conducted into the validity, usefulness and applicability of the proposed curriculum model and its criteria. A possible procedure and order would be the following:

- (a) Stage 1: The design of a curriculum unit (containing both physics and chemistry) based on the model and criteria.
- (b) Stage 2: Trial and evaluation of these units in a representative sample of schools. The teachers involved in these trials should be fully informed of the reasoning and rationale behind the trial materials.
- (c) Stage 3: Rejection, amendment or acceptance of the model and criteria in the light of experience gained in the trial schools.
- (d) Stage 4: If the model and criteria are considered to be viable, Stage 1 of the procedure is then applied to a complete experimental curriculum.
- (e) Stage 5: Trial in a representative sample of schools.
- (f) Stage 6: Feedback and refinement.
- (g) Stage 7: Trial of the improved curriculum in a larger number of schools.
- (h) Stage 8: Application of the model and criteria to other subjects, following the same procedures.
- (i) Continuous evaluation and feedback should take place during all stages of development.
- (j) Stage 9: Implementation.
- (k) Stage 10: This stage is continuous and provides for changes and adaptations without the introduction of major revisions or a complete curriculum change.

The design and trial of curriculum materials should involve a full complement of educationists, subject specialists, teachers, designers of teaching-learning aids, and pupils. Pupils should be informed of the curriculum objectives and be involved in the continuous evaluation.

- 4.1.2 Depending on the findings of the initial trial and evaluation of the model and criteria, further research into the refinement and formulation of criteria as well as the development of descriptions and/or instructions for their interpretation and application, seems to be indicated.

4.2 The curriculum for Physical Science

4.2.1 Physical Science and general education

The development of the curriculum model and criteria was based on a specific choice of an ultimate aim of education - the survival of Man as a uniquely human being. This choice was, inter alia, guided by the requirements of universality and flexibility: The aim should be acceptable and applicable to all educational, political and philosophical systems and be able to accommodate the superimposition of the goals of these systems.

It was stated that survival as the ultimate aim should be the primary determinant and consideration and that the secondary aims should not be allowed to determine the objectives, content, organization method and evaluation of the curriculum.

This point of view does not exclude the secondary aims, nor does it disparage the educational benefits that may be achieved by the attainment of these aims. The ideal curriculum would be one that provides for the effective attainment of the ultimate aim of education as well as for the attainment of the secondary educational aims.

4.2.2 A curriculum structure for general education

A suitable curriculum structure which could provide for the primary aim of science education as well as for the secondary aims suggests itself from the results of the criterion-independent evaluation of

the syllabus content. This aspect of the syllabus evaluation identified a core of essential content on which teachers and university lecturers agree. This core is sufficiently limited in the number of topics and units to allow for the addition of material specially selected to attain best all or some of the more important secondary aims of science education.

The following structure is recommended as being worthy of investigation and trial:

1. A core of "essential" content.
2. A number of additional optional units, selected and designed for specific educational purposes.

1. The core content

- (a) The core content should be based on the units and topics identified by teachers and lecturers as essential, possibly expanded in some areas after careful discussion and deliberation involving teachers, subject specialists and educationists.
- (b) The core content selected by the teachers and lecturers (Chapter 13) include approximately one half of the units contained in the present syllabus and many of the "essential" topics are also reduced in scope. An additional topic, the study of inorganic reactions, is added. This unit may take up a considerable portion of time and, to be taught effectively, will have to contain a large practical component. It is recommended that any extension of the essential core should take place only after very careful deliberation and that the length of the core should not exceed approximately 60% of the available teaching time.
- (c) Differentiation for the Higher and Standard Grades can be achieved by the existing procedure of dilution or expansion as well as by variation in emphasis. The differentiation is not necessarily limited to two grades only since the core, being basic and fundamental, may also serve the special needs of technical and agricultural high schools.

- (d) To meet the requirements of the Joint Matriculation Board for university entrance the core could be examined externally under the control or moderation of the Board.

2. The optional units

- (a) A limited number of optional units should comprise approximately 40% of the course in terms of teaching time.
- (b) The optional units should be selected from a number of groups or categories. The options in each category should be selected and designed for the attainment of a specified secondary educational aim, or for the provision for the special needs of technical, agricultural or other specialised fields of education. The number of categories will be determined by the number of units to be completed during the three year course.
- (c) Wherever possible each optional unit should be linked to one or more units of the core in order to provide for unity and integration.
- (d) Differentiation may be achieved by the procedures recommended for the core, as well as by providing different optional units for the different grades. For Higher Grade pupils provision could be made for the in-depth study of core units or of units directly related to the core, as stated in (c) above.
- (e) The design of optional units from fields outside "pure" physics and chemistry, such as astronomy, biology, earth science, applied science, etc., which can be linked to the core, should not be excluded.
- (f) The optional units, because of their number and diversity, should be assessed internally upon completion of each unit. The marks thus obtained should be added to those obtained by the external examination of the core to determine the final mark for promotion purposes. University entrance may, if the Joint Matriculation Board should require this, be based on the externally assessed core component only. If deemed essential, this double grading can be indicated by means of a system of symbols, e.g. Cb would indicate a total score of 60 - 69% (C) and a university entrance (core) score of 70 - 79% (b).

4.2.3 Advantages of the core-plus-options structure

1. The structure provides for both the primary and secondary aims of education.
2. Differentiation can be achieved more effectively and is not limited to Higher and Standard Grade only.
3. The proposed structure provides for the special interests and abilities of teachers, and for regional differences in climate, resources, technologies and industries.
4. The optional topics can, if carefully designed, provide for the special needs of the scientifically gifted pupil.
5. The options allow for the use of auto-tutorial methods. These methods may be of special value in the teaching of optional units for the Higher Grade and in meeting the needs of gifted pupils.
6. The optional topics make it possible to include studies and discussions on the more important issues related to science and science education, e.g. energy, pollution, food production, the impact of science on society, etc.
7. The opportunities provided for the integration of science topics derived from a wider spectrum of scientific disciplines make it possible to obtain the benefits claimed by the integrated science movement without distracting from the benefits claimed by the advocates of the structure-of-knowledge supporters.
8. Serving teachers may be given the opportunity to design and submit options for approval, thereby involving them in the process of curriculum design and development.

4.2.4 Disadvantages of the core-plus-options approach

1. The reduction of the compulsory content to a core narrows the scope of the curriculum content which will be covered by all pupils.

2. Too much of the success of the proposed structure depends on the ability of the teacher: the structure is not "teacher proof".
3. Handling a variety of different options in the same classroom places an additional burden on the teacher and may create insuperable organizational problems.
4. A single textbook cannot provide for the core and all the optional units. The provision of a core text as well as separate unit or topic booklets would be expensive.
5. Additional and special equipment may be needed for the effective teaching of some optional topics. This, too, will increase the cost.
6. Pupils moving to another town or school may have to do different options from those offered at their previous schools.
7. If one inherits the advantages of integrated science and of the structure-of-knowledge approach, one also inherits the disadvantages of both.

4.2.5 A cautionary note

Many of the disadvantages mentioned in the previous paragraph may be countered. Pupil movement from one school to another, for example, will offer no greater problem than at present if the optional units are required to be completed within a school term. Marks obtained for units in one school may be transferred to another.

However, "... reforming zeal must come to terms with circumstance"⁸ and the recommended curriculum structure should first be carefully studied to determine the implications for teacher education and re-education, cost of implementation, facilities and equipment required, and other limiting factors, before the initial pilot scheme and trial can be attempted.

4.3 Teaching-learning aids for science teaching

Two teaching aids - ciné films and demonstration models - were selected by pupils as being specially effective aids to understanding. The overhead projector, with its vast potential as an aid in increasing the effectiveness of demonstrations, was selected as the most

effective aid by teachers, but was placed third by pupils, 21% below the ciné projector. This result seems to indicate that teachers misuse the overhead projector as an "illuminated blackboard" or are not sufficiently trained in the effective use of overhead projection techniques.

It is recommended that

- (a) more use should be made of films in science teaching;
- (b) the design and provision of a larger range of suitable teaching models be thoroughly investigated;
- (c) both the pre-service and in-service education of science teachers should make special provision for instruction in the effective use and special value of the overhead projector in science teaching.

It should be pointed out that teachers complain that the appropriate films are often not available at the time they are required. It is suggested that the transfer of films to videotape for use with closed-circuit television may provide a possible solution.

4.4 The textbook as an aid

The importance of the textbook in the teaching of Physical Science requires that textbooks which are scientifically correct, effective and readable in presentation, be available. It is recommended that this can best be achieved in a democratic society by competition in a free-enterprise system. The availability of a number of textbooks to choose from will lead to improved writing and production. To achieve this the limitation of choice to a fixed number of approved textbooks by some departments of education, should be dispensed with.

4.5 Curriculum evaluation

External evaluation of science education is conducted at irregular intervals⁹ but no permanent system of continuous evaluation is applied in South Africa. It is urgently recommended that, as a starting-point, the results of the yearly external examinations be used for this purpose along the lines suggested in Section 3.1.5 of this chapter.

5. IN CONCLUSION

The design of a theoretical model and criteria for the construction of a curriculum for Physical Science, is but a single facet of the field of curriculum study and an even smaller aspect of the methodology of education. The conclusion that the proposed model and criteria may be viable and feasible, not only in the limited field of physics and chemistry teaching but also in other subject areas, contains the promise and the hope that, by the combined and cumulative efforts of educationists and researchers, a universally acceptable curriculum theory may eventually be constructed.

REFERENCES AND NOTES

1. This dissemination of the Anglo-American interpretation of the term "curriculum" is perhaps best traced through the articles in consecutive issues of the UNESCO publications "The teaching of basic sciences" series. Publications in this series are, inter alia, New Trends in Chemistry Teaching (four volumes from 1967 to 1975), New Trends in Physics Teaching (three volumes from 1968 to 1976), and New Trends in Integrated Science Teaching (four volumes from 1971 to 1976).
2. A.A. Strassenburg, "The process of course and curriculum development", John L. Lewis (ed.), New Trends in Physics Teaching III. (Paris: Unesco, 1976), pp. 120 - 136.
3. Robert J. Trotter, "Discoverists vs. behaviorists: Muddle of contrasting theories", Science News, 103: 12: 192 (24 March 1973).
4. Ibid.
5. APPENDIX I.
6. APPENDIX VI.
7. Of the many chemistry lecturers who commented on this order, two used this expression.
8. Cited in Ben Taute, Opvoedende Onderwys. (Stellenbosch: University Publishers and Booksellers, 1955), p. 112. The original source is only indicated as "a report of a Scottish Commission in 1946".
9. Such an investigation is being conducted at present (1977 - 1978) by the Human Sciences Research Council, Pretoria.

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CURRICULUM MATERIALS

GERMANY

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APPENDIX ILIST OF SYLLABUSES AND CURRICULA ANALYSED

1. Chemical Bond Approach (CBA), U.S.A.
2. Chemical Education Material Study (CHEM Study), U.S.A.
3. Nuffield Chemistry (O-Level), U.K.
4. Scottish Certificate of Education Examination Board, Chemistry - Ordinary and Higher Grades, Scotland.
5. Nordrhein-Westfalen, Gymnasiale Oberstufe: Curriculum Chemie, Germany.
6. Physical Science Study Committee Physics (PSSC), U.S.A.
7. The Project Physics Course (Project Physics), U.S.A.
8. Nuffield Physics (O-Level), U.K.
9. Scottish Certificate of Education Examination Board, Physics - Ordinary and Higher Grades, Scotland.
10. Nordrhein-Westfalen, Gymnasiale Oberstufe: Curriculum Physik, Germany.

SYLLABUSES AND CURRICULA CONSULTED AND COMPARED

1. New York State Education Department: Chemistry - A Syllabus for Secondary Schools, U.S.A.
2. New York State Education Department: Physics - A Syllabus for Secondary Schools, U.S.A.
3. Nuffield Advanced Chemistry, U.K.
4. Nuffield Advanced Physics, U.K.
5. Nuffield Advanced Physical Science, U.K.
6. Nuffield Secondary Science, U.K.
7. Nuffield Combined Science, U.K.
8. Scottish Integrated Science Project, Scotland.
9. Science 5 - 13, U.K.
10. Schools Council Integrated Science Project (SCISP), U.K.
11. Australian Science Education Project, (Australia).
12. Projekt Leerpakkeontwikkeling Natuurkunde (Physics), The Netherlands.

APPENDIX IIA. LIST OF COUNTRIES AND INSTITUTIONS VISITED1. ISRAEL

- (a) Department of Science Teaching, Weizmann Institute of Science, Rehovot, Israel.
- (b) Department of Education and Culture, Jerusalem, Israel.

2. FRANCE

- (a) Ministry of Education, Paris.
- (b) UNESCO Headquarters, Paris.

3. WEST-GERMANY

- (a) Sekretariat der Ständigen Konferenz der Kultusminister der Länder in der Bundesrepublik Deutschland (Secretariat of the Permanent Conference of Ministers of Education of the States in the Federal Republic of Germany), Bonn.

4. GREAT BRITAIN

- (a) The British Council, London.
- (b) South London Science Centre.
- (c) Schools Information Centre on the Chemical Industry.
- (d) Various secondary schools (Boys', Girls', Co-educational; Comprehensive and Grammar Schools) in London.
- (e) Centre for Studies in Science Education, University of Leeds, Leeds.
- (f) Secondary Schools (one comprehensive, one open plan comprehensive), Leeds area.
- (g) Teachers' Centre, Leeds.
- (h) Dundee College of Education, Dundee.
- (i) The Scottish Centre for Mathematics, Science and Technical Education, Dundee.
- (j) Secondary Schools, Edinburgh (one open plan).

- (k) Scottish Schools Science Equipment Research Centre,
Edinburgh.
- (l) British Council Coures 725: Curriculum Development in
Science: Strategies and Trends, Leeds and Dundee.

B. LIST OF COUNTRIES REPRESENTED IN THE INTERVIEWS

1. Australia
2. Canada
3. Cyprus
4. Denmark
5. France
6. Indonesia
7. Israel
8. Jamaica
9. Kenya
10. Kuwait
11. Malaysia
12. Netherlands
13. New Zealand
14. Nigeria
15. Norway
16. Sweden
17. Venezuela
18. West-Germany
19. Not representing a country: UNESCO

NOTE: With the exception of France, Israel, West-Germany and UNESCO the interviews were conducted either singly or in small groups with delegates to the British Council Course 725 at Leeds and Dundee, 5 - 24 September 1977.

APPENDIX III

QUESTIONNAIRE FOR TEACHERSA. GENERAL INFORMATION

(Where applicable, a cross only should be made in the appropriate block.)

1. Sex of teacher: MALE: FEMALE:
2. Qualifications:
- 2.1 Do you have a university degree in the natural sciences (B.Sc., etc.)? Yes No
- 2.2 Number of year courses passed in PHYSICS
- 2.3 Number of year courses passed in CHEMISTRY
- 2.4 Number of FULL YEARS experience in the teaching of Physical Science
- 2.5 University attended for your basic degree (Bachelor's degree) in the sciences.
- 2.6 Year in which basic degree (B-degree) was obtained ..
- 2.7 Do you have a professional teaching qualification (teacher's certificate or diploma)? Yes No
3. Type of school:
- 3.1 Province in which school is situated
- 3.2 Sex of pupils: Both sexes Boys only Girls only
- 3.3 Area in which school is situated: City Suburb Village
- 3.4 Medium of instruction: Afrikaans English Both media
- 3.5 Number of pupils offering Physical Science in Std.10: Afr. Eng. Total
4. Aids:
- 4.1 Are the following teaching aids available?
1. Ciné projector 2. Loop film projector
3. Overhead projector 4. Slide projector
5. Episcopo 6. Closed circuit TV
7. Other (specify)
- 4.2 Which of the aids do you find specialy useful/effective in the teaching of Physical Science?
-
- (Numbers only please!)

4.3 Which of the aids available to you, do you use regularly?

(Numbers only, please!)

4.4 Do you use models (e.g. orbital shapes, molecule shapes, electric motor, etc.) in your teaching?

Yes

No

4.5 Are these models used by you mainly:- (a) home-made _____
(b) supplied by the Department, or bought

5. The text-book as learning aids:

5.1 Do your pupils in standards 9 and 10 use one of the available South African text-books?

Yes

No

5.2 Do your pupils use an overseas text-book or text-books?

Yes

No

5.3 Do your pupils regularly use an additional South African text-book?

Yes

No

5.4 Do your pupils use an additional overseas text-book?

Yes

No

5.5 Do you supply pupils with additional notes?

Yes

No

5.6 The following questions refer to the South African text-book used by your pupils in standards 9 and 10:

5.6.1 Does the book cover the syllabus fully?

Yes

No

5.6.2 Are the explanations sufficiently clear?

Yes

No

5.6.3 Is the language used of such a nature (standard) that pupils can learn from the book without much difficulty?

Yes

No

5.6.4 Are the illustrations effective?

Yes

No

5.6.5 Do you use the questions at the end of chapters (if any) in your teaching?

Yes

No

5.7 Do you use a separate laboratory manual in your teaching (practical work)?

Yes

No

6. Laboratory facilities

6.1 Does your school have a laboratory for Physical Science?

Yes

No

6.2 Is the laboratory available to you at all times?

Yes

No

6.3 Do you have sufficient apparatus available for carrying out practical work in small groups (2 - 4 pupils)?

Yes

No

6.4 Do you have sufficient apparatus available for carrying out teacher demonstrations?

Yes

No

6.5 Does the length of the syllabus allow you sufficient time for regular practical work?

Yes

No

6.6 Do your pupils do practical work outside regular school hours? Yes No

6.7 Are the services of an official laboratory assistant available to you? Yes No

7. Length of the syllabus:

7.1 Do you think that the syllabus for Physical Science is:-
 (a) Too long?
 (b) of about the correct length? HG SG
 (c) too short?

Please fill in (a), (b) or (c) in the blocks.

7.2 What approximate percentage of the prescribed syllabus for standards 9 and 10 can you comfortably complete in the 2 years of the course? % HG % SG

7.3 Do you teach Physical Science for the Higher Grade and Standard Grade in the same class group or separately? Together Separate

7.4 Does the length of the syllabus have an adverse effect on the way you teach the subject? Yes No

8. Degree of difficulty:

8.1 Would you judge Physical Science, in comparison with the majority of school subjects, to be:-
 (a) more difficult?
 (b) of comparable degree of difficulty?
 (c) less difficult?

Please fill in (a), (b) or (c) in the block:

8.2 Would you judge the present syllabus to be within the general ability of the pupils offering it? Yes No

8.3 If you have answered NO to Question 8.2, for what approximate percentage of your present senior class (Std. 10 or Form 12) would you judge the syllabus to be within their ability to obtain a percentage comparable to their general class performance? %

8.4 Do you think that the physics and chemistry components are of approximate equal degree of difficulty? Yes No

8.5 If not, which one would you judge to be more difficult?
 Physics/Chemistry

9. Interest value of the syllabus:

9.1 Would you say that the majority of pupils find the prescribed syllabus (content + prescribed practical work) interesting?

Yes

No

9.2 Evaluate the various topics of the CORE SYLLABUS on the basis of interest value for the pupil, by circling the number of your choice on the scale:

1. High interest value
2. Average interest value
3. Low interest value.

STANDARD 8 (FORM 10)

- | | | | | |
|----|---|---|---|---|
| 1. | <u>LIGHT</u> (Light transfers energy; how light is propagated) | 1 | 2 | 3 |
| 2. | <u>SOUND</u> (Production; propagation; characteristics; sound and the ear) | 1 | 2 | 3 |
| 3. | <u>HEAT, WORK AND INTERNAL ENERGY</u> (Effects of temperature change; heat - a form of energy; equivalence of heat and work; heat, work, internal energy and thermal energy; fusion, evaporation, condensation and latent heat) | 1 | 2 | 3 |
| 4. | <u>ELECTRICITY</u> (Measuring electrical quantities; effects of current; electromagnetic induction) | 1 | 2 | 3 |
| 5. | <u>ATOMIC STRUCTURE</u> (The nuclear atom; how atoms combine) | 1 | 2 | 3 |
| 6. | <u>CHEMICAL REACTIONS</u> (Reactivity of metals; reactions of non-metals) | 1 | 2 | 3 |
| 7. | <u>ACIDS, BASES AND SALTS</u> (Properties of acids and alkalis; neutralisation; preparation of salts) | 1 | 2 | 3 |
| 8. | <u>CHEMICAL REACTIONS AND ELECTRICITY</u> (Evidence for ions in solution; electrolysis; reactions producing electrical energy) | 1 | 2 | 3 |
| 9. | <u>REACTIONS INVOLVING IONS</u> | 1 | 2 | 3 |

STANDARD 9 (FORM 11)

- | | | | | |
|----|--|---|---|---|
| 1. | <u>VECTORS</u> (Displacement; displacement and force as vectors; equilibrium of forces; components; velocity and acceleration) | 1 | 2 | 3 |
| 2. | <u>DISPLACEMENT, VELOCITY-TIME RELATIONSHIPS</u> (Graphs of displacement/time and velocity/time: included to derive equations of motion) | 1 | 2 | 3 |
| 3. | <u>BODIES IN MOTION</u> (Newton's 1st law; Newton's 2nd law; circular motion; Newton's 3rd law; momentum; work, energy and power) | 1 | 2 | 3 |

- | | | | | |
|-----|--|---|---|---|
| 4. | <u>ELECTROSTATICS</u> (Charge by contact; electroscope; conservation of charge; force between charges; Coulomb's law; electric fields; potential difference; field strength; quantisation of charge (Millikan's experiment)) | 1 | 2 | 3 |
| 5. | <u>THE ELECTRIC CURRENT</u> (Current as flow of charge; maintenance of PD; force on current-bearing conductors; magnetic field and its vector B; resistance and Ohm's law; heating effect; alternating current) | 1 | 2 | 3 |
| 6. | <u>THERMIONIC EMISSION</u> (The phenomenon and its application in the diode and cathode ray tube) | 1 | 2 | 3 |
| 7. | <u>LIGHT</u> (Diffraction and interference; colour) | 1 | 2 | 3 |
| 8. | <u>ELECTROMAGNETIC WAVES</u> (Discussion in terms of electric and magnetic vectors; produced by accelerating charged particles; Maxwell's prediction; light as EM wave; electromagnetic spectrum) | 1 | 2 | 3 |
| 9. | <u>PARTICLES, WAVES AND QUANTA</u> (Particle nature of photons and electrons; wave nature of electrons and photons) | 1 | 2 | 3 |
| 10. | <u>THE ATOMIC NUCLEUS</u> (Rutherford's experiment; natural radioactivity; artificial radioactivity) | 1 | 2 | 3 |
| 11. | <u>ATOMIC STRUCTURE</u> (Atom models; quantum numbers; orbitals; electron filling of orbitals; electronic structure and the periodic table; valency) | 1 | 2 | 3 |

STANDARD 10 (FORM 12)

- | | | | | |
|------|---|---|---|---|
| 1. | <u>CHEMICAL BONDING</u> (The concept "molecule"; the covalent bond model; molecular geometry; polar covalent bond; ionic bond; metallic bond; intermolecular forces) | 1 | 2 | 3 |
| 2. | <u>THREE PHASES OF MATTER</u> (Gases; the ideal gas, non-ideal gases; calculations on gas laws; liquids; solids: the concept "lattice", bonding in solids; phase equilibrium) | 1 | 2 | 3 |
| 3. | <u>SOLUTIONS</u> | 1 | 2 | 3 |
| 4. | <u>RATES OF CHEMICAL REACTIONS</u> | 1 | 2 | 3 |
| 5. | <u>EQUILIBRIUM IN CHEMICAL REACTIONS</u> (The equilibrium constant; application of equilibrium principles in industry; factors effecting equilibrium; equilibrium in solutions; acids and bases; ionisation of water) | 1 | 2 | 3 |
| 5(a) | <u>ACID-BASE MODELS</u> (proton transfer; titrations; pH; acid-base properties of hydroxides of Period 3) | 1 | 2 | 3 |
| 6. | <u>ELECTROCHEMICAL CELLS</u> | 1 | 2 | 3 |
| 7. | <u>OXIDATION-REDUCTION</u> | 1 | 2 | 3 |
| 8. | <u>ORGANIC CHEMISTRY</u> (What it is; structures; nomenclature; alkanes, alkenes, alkynes; halo-alkanes; alcohols; carboxylic acids; esters) | 1 | 2 | 3 |

B. AIMS (OBJECTIVES) OF THE SYLLABUS

1. Are the aims for the syllabus in your opinion:-

(a) comprehensive enough to relate to all aspects of the syllabus content? Yes No(b) specific and explicit enough to provide the teacher with clear guidance about what should be attained with each section of the syllabus? Yes No2. Do you refer to the official aims when planning your work? Yes No3. Does a perceptible relationship exist between the syllabus aims and questions set in the Departmental examinations? Yes No4. Arrange the seven aims given below in order of decreasing importance according to your opinion. Write down the NUMBERS only of the aims in the blocks provided.4.1 To prepare pupils to pass a final examination.Most important4.2 To provide pupils with scientific knowledge.(1) 4.3 To train pupils in scientific methods of work and ways of thinking.(2) 4.4 To inculcate scientific attitudes and ideals (such as objectivity, honesty, application to a task, preparedness to change views in the light of new evidence, etc.)(3) (4) 4.5 To lead the pupils towards appreciation and reverence for the wonders of Creation and nature.(5) (6) 4.6 To train the pupils in the skillful use of scientific instruments and apparatus.(7) 4.7 To arouse in pupils an interest in natural phenomena, scientific literature, scientific hobbies, etc.Least important

5. For which of the following aims should a syllabus for Physical provide? Mark with a cross in the appropriate column:

| | Specifi- cally | Indi- rectly | Not at all |
|--|-------------------|-----------------|---------------|
| 5.1 To provide pupils with aspects of <u>knowledge</u> of Physics and Chemistry which are of importance today _____ | | | |
| 5.2 To provide pupils with knowledge that is <u>educationally functional</u> , i.e. knowledge specially selected to bring about certain educational functions. _____ | | | |
| 5.3 To provide the school leaver with a picture of the status of the subjects (Physics and Chemistry) in our contemporary civilisation. _____ | | | |

| | | Specifi- cally | Indi- rectly | Not at all |
|-------|--|-------------------|-----------------|---------------|
| 5.4 | To provide pupils with an understanding of the nature of Physics and Chemistry as science. _____ | | | |
| 5.5 | To prepare pupils for continued study of the sciences or applied sciences. _____ | | | |
| 5.6 | To provide pupils with an understanding of the application of scientific principles in technology and industry. _____ | | | |
| 5.7 | To prepare pupils for life in a technological society. _____ | | | |
| ----- | | | | |
| 5.8 | To provide pupils with an understanding of the orderly framework of concepts, laws and theories upon which a science is constructed. _____ | | | |
| 5.9 | To provide pupils with an understanding of the ways (methods) by which scientists work (the so-called 'scientific method'). _____ | | | |
| ----- | | | | |
| 5.10 | To develop in pupils an <u>enquiring approach</u> to the solution of problems. _____ | | | |
| 5.11 | To develop an attitude of objectivity in pupils. _____ | | | |
| 5.12 | To develop an attitude of scientific honesty in pupils. _____ | | | |
| ----- | | | | |
| 5.13 | To lead pupils towards appreciation and reverence for the wonders of Nature and Creation. _____ | | | |
| 5.14 | To make pupils aware of the power as well as the limitations of science. _____ | | | |
| ----- | | | | |
| 5.15 | To train pupils in the skills of using and handling scientific instruments and apparatus. _____ | | | |
| ----- | | | | |
| 5.16 | To arouse in pupils an interest in scientific vocations, scientific literature and activities. _____ | | | |
| ----- | | | | |

C. SYLLABUS CONTENT

1. The content outlined below is based on the higher and standard grade syllabuses of the J.M.B., supplemented with topics generally found in overseas school syllabuses.
2. If you would like to add further topics, please use the spaces provided for that purpose.
3. If more details about the main topics are required, please refer to the attached elaborations. The topics and sub-headings of the elaborations are numbered in the same sequence as in the questionnaire below.
4. Mark with a cross in the appropriate column to indicate the inclusion of a particular topic is, in your opinion, ESSENTIAL, DESIRABLE or UNNECESSARY. If you think that any topic may be effectively taught before the senior phase (std. 8), please indicate this by marking with an X in the last column.

| Brief description of content | Essen- tial | Desirable | Unneces- sary | Pre- Std.8 |
|--|----------------|-----------|------------------|---------------|
| 1. <u>Scientific procedures</u> | | | | |
| 1.1 Scientific methods of work | | | | |
| 1.2 Uncertainty and validity of measurements | | | | |
| 1.3 Scientific communication | | | | |
| 1.4 | | | | |
| 1.5 | | | | |
| 1.6 | | | | |
| 2. <u>Vectors</u> | | | | |
| 2.1 Displacement | | | | |
| 2.2 Displacement and force as examples of vectors | | | | |
| 2.3 Equilibrium of forces | | | | |
| 2.4 Components | | | | |
| 2.5 Velocity and acceleration | | | | |
| 2.6 | | | | |
| 2.7 | | | | |
| 2.8 | | | | |
| 3. Displacement-time and velocity-time relationships | | | | |
| 3.1 Graphic representations | | | | |

| Brief description of content | Essen- tial | Desirable | Unneces- sary | Pre- Std.8 |
|---|----------------|-----------|------------------|---------------|
| 3.2 Experimental investigation _____ | | | | |
| 3.3 Equations of motion _____ | | | | |
| 3.4 | | | | |
| 3.5 | | | | |
| 3.6 | | | | |
| 4. <u>Bodies in motion</u> | | | | |
| 4.1 Newton's first law _____ | | | | |
| 4.2 Newton's second law _____ | | | | |
| 4.3 Circular motion _____ | | | | |
| 4.4 Newton's law of universal gravitation _____ | | | | |
| 4.5 Newton's third law _____ | | | | |
| 4.6 Momentum _____ | | | | |
| 4.7 Work, energy and power _____ | | | | |
| 4.8 | | | | |
| 4.9 | | | | |
| 4.10 | | | | |
| 4.11 | | | | |
| 4.12 | | | | |
| 5. <u>Electrostatics</u> | | | | |
| 5.1 Revision of former qualitative study of electrostatics _____ | | | | |
| 5.2 Force between charges: Coulomb's law _____ | | | | |
| 5.3 Electric fields _____ | | | | |
| 5.4 Quantisation of charge: Millikan's experiment _____ | | | | |
| 5.5 | | | | |
| 5.6 | | | | |
| 5.7 | | | | |

| Brief description of content | Essen- tial | Desirable | Unneces- sary | Pre- Std.8 |
|--|----------------|-----------|------------------|---------------|
| 6. <u>The electric current</u> | | | | |
| 6.1 Measuring electrical quantities: | | | | |
| 6.1.1 Current; the ampere _____ | | | | |
| 6.1.2 Potential difference; the volt _____ | | | | |
| 6.1.3 Resistance; the ohm _____ | | | | |
| 6.1.4 Emf and internal resis- tance _____ | | | | |
| 6.2 Effects of electric current: | | | | |
| 6.2.1 Rise in temperature _____ | | | | |
| 6.2.2 Magnetic effects _____ | | | | |
| 6.2.3 Electromagnetic induc- tion _____ | | | | |
| 6.3 Electric current as flow of charges | | | | |
| 6.4 Force on current-bearing conductors | | | | |
| 6.5 Magnetic field and Field strength | | | | |
| 6.6 Resistance and Ohm's law _____ | | | | |
| 6.7 Heating effect (Quantitatively) _____ | | | | |
| 6.8 Alternating current _____ | | | | |
| 6.9 | | | | |
| 6.10 | | | | |
| 6.11 | | | | |
| 6.12 | | | | |
| 7. <u>Electronics</u> | | | | |
| 7.1 Thermionic emission _____ | | | | |
| 7.2 Thermionic diode and applications _____ | | | | |
| 7.3 Vacuum triode and applications _____ | | | | |
| 7.4 Transistor (junction diode and triode) _____ | | | | |
| 7.5 Reception and modulation of radio waves _____ | | | | |
| 7.6 | | | | |
| 7.7 | | | | |

| Brief description of content | Essen- tial | Desirable | Unneces- sary | Pre- Std. 8 |
|---|----------------|-----------|------------------|----------------|
| 7.8 | | | | |
| 7.9 | | | | |
| 8. <u>Waves</u> | | | | |
| 8.1 Vibration as introduction to periodic motion; terminology _____ | | | | |
| 8.2 Graphic representation of a disturbance versus time _____ | | | | |
| 8.3 Polarisation, extinction, superposition _____ | | | | |
| 8.4 Energy transformations _____ | | | | |
| 8.5 Interference and diffraction _____ | | | | |
| 8.6 Standing waves _____ | | | | |
| 8.7 | | | | |
| 8.8 | | | | |
| 8.9 | | | | |
| 8.10 | | | | |
| 9. <u>Sound</u> | | | | |
| 9.1 Production of sound _____ | | | | |
| 9.2 Transmission of sound _____ | | | | |
| 9.3 Characteristics of sound: | | | | |
| 9.3.1 Speed of sound _____ | | | | |
| 9.3.2 Reflection of sound _____ | | | | |
| 9.4 Sound and the ear: | | | | |
| 9.4.1 Loudness and pitch _____ | | | | |
| 9.4.2 Noise and musical notes _____ | | | | |
| 9.5 | | | | |
| 9.6 | | | | |
| 9.7 | | | | |
| 10. <u>Light</u> | | | | |
| 10.1 Light transfers energy _____ | | | | |
| 10.2 How light travels _____ | | | | |

| Brief description of content | Essential | Desirable | Unnecessary | Pre-Std.8 |
|--|-----------|-----------|-------------|-----------|
| 10.3 Rectilinear propagation of light _____ | | | | |
| 10.4 Reflection _____ | | | | |
| 10.5 Refraction _____ | | | | |
| 10.6 Prisms _____ | | | | |
| 10.7 Lenses _____ | | | | |
| 10.8 Diffraction and interference _____ | | | | |
| 10.9 Colour of light _____ | | | | |
| 10.10 Electromagnetic waves _____ | | | | |
| 10.11 Light as electromagnetic wave _____ | | | | |
| 10.12 The electromagnetic spectrum _____ | | | | |
| 10.13 | | | | |
| 10.14 | | | | |
| 10.15 | | | | |
| 11. <u>Particles, waves and quanta</u> | | | | |
| 11.1 Particle nature of matter _____ | | | | |
| 11.2 Particle nature of electrons and photons _____ | | | | |
| 11.3 Wave nature of electrons and Photons _____ | | | | |
| 11.4 Quantisation of energy as an explanation for line spectra _____ | | | | |
| 11.5 | | | | |
| 11.6 | | | | |
| 11.7 | | | | |
| 12. <u>The atomic nucleus</u> | | | | |
| 12.1 Rutherford's scattering experiment _____ | | | | |
| 12.2 Natural radioactivity _____ | | | | |
| 12.3 Artificial radioactivity _____ | | | | |
| 12.4 Mass and energy in nuclear reactions _____ | | | | |
| 12.5 Energy of the sun _____ | | | | |
| 12.6 Particle accelerators _____ | | | | |

| Brief description of content | Essen- tial | Desirable | Unneces- sary | Pre- Std.8 |
|---|----------------|-----------|------------------|---------------|
| 12.7 Nuclear fission _____ | | | | |
| 12.8 Chain reactions _____ | | | | |
| 12.9 Nuclear Fusion _____ | | | | |
| 12.10 | | | | |
| 12.11 | | | | |
| 12.12 | | | | |
| 13. <u>Atomic structure</u> | | | | |
| 13.1 Revision and expansion of termino- logy _____ | | | | |
| 13.2 Development of atomic models _____ | | | | |
| 13.3 Quantum numbers _____ | | | | |
| 13.4 Orbitals _____ | | | | |
| 13.5 Aufbau _____ | | | | |
| 13.6 Electronic structure and the periodic table _____ | | | | |
| 13.7 Valency _____ | | | | |
| 13.8 | | | | |
| 13.9 | | | | |
| 13.10 | | | | |
| 14. <u>Chemical bonding</u> | | | | |
| 14.1 The concept "molecule" _____ | | | | |
| 14.2 Covalent bond model _____ | | | | |
| 14.3 Molecular geometry _____ | | | | |
| 14.4 Polar covalent bonding _____ | | | | |
| 14.5 Ionic bond model _____ | | | | |
| 14.6 Metallic bonding _____ | | | | |
| 14.7 Intermolecular forces _____ | | | | |
| 14.8 | | | | |
| 14.9 | | | | |
| 14.10 | | | | |
| 15. <u>Work, heat and internal energy</u> | | | | |
| 15.1 Effect of change in temperature | | | | |

| Brief description of content | Essential | Desirable | Unnecessary | Pre-Std.8 |
|---|-----------|-----------|-------------|-----------|
| 15.2 Heat - a form of energy _____ | | | | |
| 15.3 Equivalence of heat and work _____ | | | | |
| 15.4 Rise in temperature due to work _____ | | | | |
| 15.5 Rise in temperature by heat transfer _____ | | | | |
| 15.6 Heat capacity and specific heat capacity _____ | | | | |
| 15.7 Internal energy and thermal energy _____ | | | | |
| 15.8 Fusion, evaporation, condensation and latent heat _____ | | | | |
| 15.9 | | | | |
| 15.10 | | | | |
| 15.11 | | | | |
| 16. <u>The three phases of matter</u> | | | | |
| 16.1 Brief resumé of the kinetic-molecular model of matter _____ | | | | |
| 16.2 Gases: | | | | |
| 16.2.1 The ideal gas; gas laws; Kelvin scale of temperature; S.T.P. _____ | | | | |
| 16.2.2 Non-ideal gases _____ | | | | |
| 16.2.3 Simple gas law calculations _____ | | | | |
| 16.3 Liquids _____ | | | | |
| 16.4 Solids: | | | | |
| 16.4.1 The concept "lattice" _____ | | | | |
| 16.4.2 Bonding in solids _____ | | | | |
| 16.5 Phase equilibrium _____ | | | | |
| 16.6 | | | | |
| 16.7 | | | | |
| 16.8 | | | | |
| 17. <u>Solutions</u> | | | | |
| 17.1 The nature of a solution _____ | | | | |
| 17.2 Intermolecular forces and solubility _____ | | | | |
| 17.3 Ion formation in solutions _____ | | | | |

| Brief description of content | Essen- tial | Desirable | Unneces- sary | Pre- Std. 8 |
|--|----------------|-----------|------------------|----------------|
| 17.4 Hydration and hydration energy _____ | | | | |
| 17.5 Concentration of solutions; standard solutions _____ | | | | |
| 17.6 | | | | |
| 17.7 | | | | |
| 17.8 | | | | |
| 18. <u>Rates of chemical reactions</u> | | | | |
| 18.1 Factors affecting the rates of reac- tions _____ | | | | |
| 18.2 Collision theory _____ | | | | |
| 18.3 Activation energy and the activated complex _____ | | | | |
| 18.4 Importance of the slowest (rate determining) step _____ | | | | |
| 18.5 Exothermic and endothermic reactions | | | | |
| 18.6 | | | | |
| 18.7 | | | | |
| 18.8 | | | | |
| 19. <u>Equilibrium in chemical reactions</u> | | | | |
| 19.1 Dynamic nature of chemical equili- brium; reversible reactions _____ | | | | |
| 19.2 The equilibrium constant _____ | | | | |
| 19.3 Application of equilibrium principles in industry _____ | | | | |
| 19.4 Factors affecting equilibrium _____ | | | | |
| 19.5 Energy and the equilibrium condi- tion _____ | | | | |
| 19.6 Entropy and the equilibrium condi- tion _____ | | | | |
| 19.7 Equilibrium: a compromise between energy and entropy factors _____ | | | | |
| 19.8 Solubility equilibria; solubility product _____ | | | | |
| 19.9 Acids and bases _____ | | | | |

| Brief description of content | Essen- tial | Desirable | Unneces- sary | Pre- Std.8 |
|---|----------------|-----------|------------------|---------------|
| 19.10 Ionisation of water _____ | | | | |
| 19.11 | | | | |
| 19.12 | | | | |
| 19.13 | | | | |
| 20. <u>Acid-base models</u> | | | | |
| 20.1 Arrhenius model _____ | | | | |
| 20.2 Lowry-Bronsted model; protolysis _____ | | | | |
| 20.3 Acid-base titrations _____ | | | | |
| 20.4 pH _____ | | | | |
| 20.5 Trends in acid-base properties of the hydroxides of period 3 _____ | | | | |
| 20.6 | | | | |
| 21. <u>Electrochemical cells</u> | | | | |
| 21.1 The Cu-Zn Cell and its chemistry _____ | | | | |
| 21.2 Half-cell reactions; electrons in half-cell reactions; net reaction _____ | | | | |
| 21.3 Oxidation and reduction in terms of electrons _____ | | | | |
| 21.4 Half-cell potentials _____ | | | | |
| 21.5 Standard electrode potentials _____ | | | | |
| 21.6 Corrosion _____ | | | | |
| 21.7 Electrolytic cells and electrolysis _____ | | | | |
| 21.8 | | | | |
| 21.9 | | | | |
| 21.10 | | | | |
| 22. <u>Oxidation-reduction</u> | | | | |
| 22.1 Oxidation and reduction in terms of electron transfer; half-reaction method of balancing equations _____ | | | | |
| 22.2 Oxidation numbers; oxidation number method of balancing equations _____ | | | | |

| Brief description of content | Essential | Desirable | Unnecessary | Pre-Std.8 |
|--|-----------|-----------|-------------|-----------|
| 22.3 Trend in oxidising and reducing properties of the elements down main groups I and VII and across period 3 | | | | |
| 22.4 Redox properties of selected transition elements | | | | |
| 23. <u>Organic chemistry</u> | | | | |
| 23.1 What is organic chemistry? Introduction | | | | |
| 23.2 Structures of compounds | | | | |
| 23.3 Nomenclature | | | | |
| 23.4 Organic compounds: | | | | |
| 23.4.1 Hydrocarbons: Alkanes, alkenes, alkynes | | | | |
| 23.4.2 Halo-alkanes | | | | |
| 23.4.3 Alcohols | | | | |
| 23.4.4 Carboxylic acids | | | | |
| 23.4.5 Esters | | | | |
| 23.5 | | | | |
| 23.6 | | | | |
| 23.7 | | | | |
| 23.8 | | | | |
| 23.9 | | | | |
| 23.10 | | | | |
| 24. <u>Systematic inorganic chemistry</u> | | | | |
| A study of selected reactions | | | | |
| (a) to apply principles developed in theory | | | | |
| (b) to obtain practice in the writing and balancing of equations | | | | |
| | | | | |
| | | | | |
| | | | | |

D. TEACHING METHODS

T18

The following code numbers indicate some of the more important general teaching methods. Use these code numbers only to indicate those methods which you usually employ in the teaching of a particular section of the work.

METHOD CODES

| <u>DESCRIPTION</u> | <u>CODE</u> |
|--|-------------|
| 1. <u>Lecture methods</u> | |
| 1.1 Traditional lecture method according to text-book contents, using the chalk board as main aid | 10 |
| 1.2 Lecture method according to text-book content, using overhead projector as main aid | 11 |
| 1.3 Lecture method according to text-book contents, complemented by only the <u>prescribed</u> demonstrations/ pupil practicals ... | 12 |
| 2. <u>Demonstration methods</u> | |
| 2.1 Lessons as a rule <u>followed by</u> a demonstration as illustration or verification | 20 |
| 2.2 Lesson as a rule <u>based on</u> a demonstration (usually designed as a problem to be <u>solved</u>) from which the further development of the lesson is evolved inductively..... | 21 |
| 2.3 Lesson <u>PLUS</u> demonstrations as an integrated unit | 22 |
| 3. <u>Activity methods</u> | |
| 3.1 Lessons as a rule <u>followed by</u> pupil practicals as illustration, verification or application | 30 |
| 3.2 Lesson <u>based on</u> data obtained from pupil and/or class practicals | 31 |
| 3.3 Lesson completely based on <u>self-discovery</u> by pupil experimentation | 32 |

-
- Which one of the foregoing methods do you, as a rule, apply most often in the teaching of Physical Science for Senior Certificate classes?
 - Which one of the foregoing methods, whether you use them or not, do you think is the most suitable for the teaching of the subject?
 - Are you of the opinion that different sections of the syllabus are better taught by using specific methods, i.e. that not all sections of the syllabus can be taught effectively by using the same general method? YES NO
 - Is your method of teaching greatly influenced by the fact that your pupils have to pass an external examination? YES NO
 - Is your method of teaching determined or influenced by the method of presentation employed in the text-book used by your pupils? YES NO

APPENDIX IV

QUESTIONNAIRE FOR PUPILS IN STD 10

Complete this questionnaire by making a cross only in the appropriate block or column.

A. THE SCHOOL

The school is situated in a city suburb village

The medium of instruction is Afrikaans English Both media

It is a school for boys girls boys and girls

B. PERSONAL PARTICULARS

Sex: Male Female

Age, last birthday: 15 16 17 18 19 Older than 19

Course: Matriculation exemption Without exemption

Grade: Higher grade Standard grade

Home language: Afrikaans English Afr. + Engl. Other

C. QUESTIONNAIRE

| | YES | NO | UNCERTAIN |
|--|-----|----|-----------|
| 1. Did you like doing Science in the primary school? _____ | | | |
| 2. Did you like General Science in the Junior Secondary Course (Stds 5 - 7)? _____ | | | |
| 3. Do you like senior Physical Science as a school subject? _____ | | | |
| 4. Are you interested in articles, lectures, talks, radio and TV-programmes, etc. about science? _____ | | | |
| 5. Do you subscribe to, or do you regularly read, scientific magazines, e.g. ARCHIMEDES? _____ | | | X |
| 6. Do you offer MATHEMATICS as a school subject? _____ | | | |
| 7. Do you offer BIOLOGY as a school subject? _____ | | | |
| 8. Do you offer PHYSIOLOGY as a school subject? _____ | | | |
| ----- | | | |
| 9. Do you think that Physical Science, compared to the other school subjects, is - | | | |
| (a) easy? _____ | | | |
| (b) reasonable or average? _____ | | | |
| (c) difficult? _____ | | | |

| | YES | NO | UNCERTAIN |
|--|-----|----|-----------|
| 10. Do you find Physical Science as a school subject - | | | |
| (a) very interesting? _____ | | | |
| (b) interesting in parts? _____ | | | |
| (c) uninteresting? _____ | | | |
| 11. Do you think that the course in Physical Science contains? | | | |
| (a) too much work? _____ | | | |
| (b) just about enough work? _____ | | | |
| (c) too little work? _____ | | | |
| 12. Do you think that Physical Science as a school subject will be of any value to you even though you may not continue your studies in a scientific field? _____ | | | |
| 13. Are you planning to follow a scientific course of study at a <u>university</u> (e.g. B.Sc., Engineering, Medicine, Agriculture, etc.)? _____ | | | |
| 14. Are you planning any further scientific or technical studies at a <u>college</u> (e.g. NTC, medical technologist, etc.)? _____ | | | |
| 15. Have you decided <u>in favour</u> of a post-matriculation course in the sciences or technology <u>as a result</u> of doing Physical Science at school? _____ | | | |
| 16. Have you decided <u>against</u> a post-matriculation course of study in the sciences or technology <u>as a result</u> of doing Physical Science at school? _____ | | | |
| ----- | | | |
| 17. Do you like carrying out practical work (experiments) yourself? _____ | | | |
| 18. Do you think that practical work performed by yourself helps you to better understand the work (theory)? _____ | | | |
| 19. Do you like demonstrations carried out by the teacher? _____ | | | |
| 20. Do you think that teacher demonstrations help you to better understand the work? _____ | | | |
| 21. Do you think that demonstrations are better aids to understanding the work than experiments performed by yourself? _____ | | | |
| 22. Do you think that teacher demonstrations and experiments performed by yourself are about equally valuable as aids to understanding the work? _____ | | | |
| ----- | | | |
| 21. Are films (movies) on aspects of Physical Science shown <u>regularly</u> to the class? _____ | | | |
| IF YOU HAVE ANSWERED <u>YES</u> TO QUESTION 23: | | | |
| 24. Do you think that films help you to better understand the work? _____ | | | |

| | YES | NO | UNCERTAIN |
|---|-----|----|-----------|
| 25. Is the overhead projector used <u>regularly</u> in the teaching of Physical Science? _____ | | | |
| IF YOU HAVE ANSWERED <u>YES</u> TO QUESTION 25: | | | |
| 26. Do you think that the use of the overhead projector helps you to better understand the work? _____ | | | |
| ----- | | | |
| 27. Are models (e.g. of the electric motor, molecular shapes, orbital shapes, etc.) used in the teaching of Physical Science? _____ | | | |
| IF YOU HAVE ANSWERED <u>YES</u> TO QUESTION 27: | | | |
| 28. Do you think that the use of models helps you to better understand the work? _____ | | | |
| ----- | | | |
| 29. Are learning programmes (booklets worked through by pupils themselves) used in the teaching of Physical Science? _____ | | | |
| IF YOU HAVE ANSWERED <u>YES</u> TO QUESTION 29: | | | |
| 30. Do you think that learning programmes help you to better understand the work? _____ | | | |
| ----- | | | |
| 31. Do you use a SOUTH AFRICAN text book? _____ | | | |
| 32. Do you find the majority of explanations in the book clear enough to follow? _____ | | | |
| 33. Do you think the explanations are too detailed? _____ | | | |
| 34. Do you think the explanations are too brief? _____ | | | |
| 35. Do you think that learning from the textbook helps you to better understand the work? _____ | | | |
| 36. Does your teacher supply additional or explanatory notes on aspects of the book? _____ | | | |
| 37. Do you prefer learning from the teacher's notes rather than from the text-book? _____ | | | |
| 38. Do you think that questions at the end of each chapter in the book help you to better understand or master the work? _____ | | | |
| ----- | | | |
| 39. Do you prefer the longer type of examination question to the shorter type where you have to select the correct answer? _____ | | | |
| 40. Do you think that the longer type of question tests your knowledge of <u>facts</u> properly? _____ | | | |
| 41. Do you think that the short type questions test your knowledge of <u>facts</u> properly? _____ | | | |
| 42. Do you think that the longer type questions test your <u>understanding</u> of the work properly? _____ | | | |
| 43. Do you think that the short type questions test your <u>understanding</u> of the work properly? _____ | | | |
| 44. Do you think that sufficient time is allowed for answering examination papers properly? _____ | | | |
| ----- | | | |

THE FOLLOWING QUESTIONS ARE MORE DIFFICULT TO ANSWER. THINK CAREFULLY ABOUT EACH QUESTION AND THEN GIVE YOUR HONEST OPINION.

| | YES | NO | UNCERTAIN |
|--|-----|----|-----------|
| 45. Did your study of Physical Science provide you with a clearer idea of the place and importance of physics and chemistry in the modern world? _____ | | | |
| 46. Do you think that by studying Physical Science you have achieved a better understanding of the nature of Physics and Chemistry as sciences? _____ | | | |
| 47. Did you, by studying Physical Science, gain a better understanding of the application of scientific principles in technology and industry? _____ | | | |
| 48. Did your study of Physical Science provide you with a clearer understanding of the orderly framework of concepts, theories and laws which form the basis of a science? _____ | | | |
| 49. Did you, by studying Physical Science, gain a better understanding of how physics and chemistry influence our everyday lives? _____ | | | |
| 50. Did you gain a clearer idea of the role of experimentation and observation as a means of obtaining scientific information? _____ | | | |
| 51. Did you discover any scientific fact or principles yourself by doing practical work? _____ | | | |
| 52. Did your study of Physical Science help you to become more proficient in the use of standard scientific apparatus (e.g. the balance, pipette, burette, etc.)? _____ | | | |
| 53. Did your study of Physical Science give you a greater respect for and appreciation of the wonders of Nature and Creation? _____ | | | |
| 54. Do you think that your education would have been poorer if you did not offer Physical Science as a school subject? _____ | | | |

55. Which of PHYSICS or CHEMISTRY do you find more difficult?

Physics

Chemistry

56. Which of PHYSICS or CHEMISTRY do you find more interesting?

Physics

Chemistry

THANK YOU FOR YOUR CO-OPERATION. HAVE YOU ANSWERED ALL THE QUESTIONS?

11. What, in your opinion, is the major lack in preparation or knowledge of first year students in your particular subject?

.....

12. Are students taught according to the newer syllabus for Physical Science better prepared for their science studies at university?

Better

Poorer

No significant difference

13. Are your first year students as a rule able to use standard laboratory equipment (e.g. burette, pipette, chemical balance, voltmeter, etc.) with confidence?

 Yes

 No

14. Are your first year students as a rule able to produce written assignments/examination answers that conform to the requirements of concise, clear scientific reporting?

 Yes

 No

15. Are your first year students as a rule able to interpret quantitative data/results (e.g. tables, graphs, etc.)?

 Yes

 No

16. Is Physical Science as a school subject essential/desirable/unnecessary as preparation for the study of physics or chemistry?

Essential

Desirable

Unnecessary

B. AIMS (OBJECTIVES) OF THE SYLLABUS

Identical to QUESTIONNAIRE FOR TEACHERS, SECTION B, QUESTIONS 5.1 TO 5.16.

C. SYLLABUS CONTENT

Identical to QUESTIONNAIRE FOR TEACHERS, SECTION C.

APPENDIX VISYLLABUS FOR PHYSICAL SCIENCE (HIGHER AND STANDARD GRADES)
OF THE CAPE EDUCATION DEPARTMENT

- (NOTE: 1. Underlined sections: For Higher Grade only.
2. Sections in square brackets [] : 1977 reductions to the syllabus.)

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**SENIOR SECONDARY COURSE: SYLLABUS FOR
PHYSICAL SCIENCE**

The following syllabus for Physical Science for the Senior Secondary Course will be introduced as from 1st January, 1974.

The syllabus will be introduced in Standard 8 in 1974 and the first Senior Certificate Examination on this syllabus will be held in November/December, 1976.

INTRODUCTION**GENERAL**

When this syllabus was drawn up the following general principles served as a guide:

1. The objective of the content of the syllabus should be to provide the pupil with a picture of Physical Science which reflects the status of the subject in our *contemporary* civilisation and, in so doing, to contribute to the development of useful and responsible citizens of this country.
2. It should be recognised that school-leaving children fall into two categories—those who will receive no further instruction in Physical Science, and those who will continue their studies in this subject at university. The former require a rounded-off picture of Physical Science, whereas the latter must be provided with a basis for their further study.
3. It should be recognised that contemporary civilisation sees two main facets of Physical Science; namely Physical Science as a Science—i.e. a fairly intellectual pursuit devoted to discovering order and pattern in the physical world; and Physical Science as a technology—i.e. a means of providing mankind with information which is immediately useful. Both facets should be adequately dealt with.
4. The subject should be taught as a structure consisting of an orderly framework of concepts, laws and theories. The framework represents the scientific aspects of the

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subject and serves to unify technologically useful facts. It is recommended that candidates offering Physical Science on the Higher Grade should also offer Mathematics at least on the Standard Grade.

5. The history of Physical Science should be drawn on only where the historical development is an aid to understanding.
6. The syllabus should contain material from *modern* physics and chemistry. If the school-leaving child is to take his place as a useful and responsible citizen, he must be provided with some knowledge of those aspects which are *now* of everyday importance; he should know something about the physical and chemical discoveries which are changing our very way of life.
7. The teaching of this subject must of necessity be simplified.
The simplification, however, must not be such that pupils are left with serious misconceptions.
Where conceptual models are used to simplify the explanation of certain phenomena (e.g. the particle model of electrical conduction), it must be made clear that these are MODELS and, as such, are not intended to serve as fully acceptable scientific explanations.
8. Physical Science should be taught as a coherent, unified subject; it should be developed as such in a logical fashion.
9. The factual content should always be presented in such a manner that the contextual unity of the subject is maintained throughout. Overemphasis of irrelevant details should be avoided at all costs.

NOTES

1. The parts italicised form the outline of the syllabus. The parts not italicised are elaborations.
2. The syllabus is divided into three separate parts of which only the last two, for Standards 9 and 10, will be examined in the final examination.
3. SI-units and derived units as given in Metrication Board publications must be defined at the appropriate stage in

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the development of the subject. This does not preclude the use of a unit by name before the "appropriate stage" has been reached.

4. It is not expected of candidates to memorise numerical values of physical constants or the Periodic Table as a whole.
In the examination, approved Periodic Tables and data sheets will be supplied where necessary.
5. In sections 10 and 11 of the Standard 9 syllabus and in the whole of the Standard 10 syllabus, emphasis should be laid on the *development of principles* which should be illustrated by a *limited* number of suitable examples.
6. International nomenclature and abbreviations must be used. Symbols and units as specified by the Metrication Board must be followed.
7. Physical Science is an experimental science. The syllabus offers ample scope for experimental work carried out by the pupils themselves. The main aims of such experimental work are the following:
 - 7.1 to help pupils understand the fundamental role played by experiment and observation in establishing and extending the body of scientific knowledge;
 - 7.2 to facilitate the learning and understanding of facts and principles;
 - 7.3 to give pupils opportunities of making their own simple "discoveries";
 - 7.4 to enable pupils to gain experience of elementary measuring techniques, and to make acquaintance with some of the measuring instruments in common use; and
 - 7.5 to enable pupils to get practice in the recording and treatment of observations, the drawing of appropriate conclusions and the presentation of results (in this connection, it is expected that pupils will gain some appreciation of what is meant by "significant figures" in recording scientific observations, and of the importance of specifying limits of accuracy.)
(Aims 7.1 and 7.2 can be achieved by treating experimental work by pupils as an integral part of the course.

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e.g. by introducing fundamental principles or important extensions or applications of these by experiments carried out by the pupils themselves. Aim 7.3 can also be achieved in this way, and by the provision of opportunities to carry out simple "open-ended" experiments.)

8. *Practical Work*

8.1 Compulsory teacher-demonstrations are indicated by a (D). The other experiments are pupil-experiments.

8.2 In Standard 8 a minimum of 12 experiments must be recorded in a practical work book. The balance between physics and chemistry must be maintained.

8.3 In Standards 9 and 10 demonstrations and pupil-experiments must be recorded in a practical work book where possible.

9. The syllabus presents one logical sequence of presentation. There are others. Teachers are free to rearrange the subject matter **WITHIN ANY ONE YEAR'S** syllabus to suit their own sequence of presentation.

10. Calculations based on formulae included in the syllabus are required, unless specifically excluded or limited in the syllabus.

11. Unless otherwise stated the derivation of formulae is required.

12. *Examination Requirements*

12.1 A minimum of three hours should be allowed for the examination.

12.2 Not more than one-third of the total marks for the examination shall be allocated to multiple-choice and short-answer types of questions.

12.3 When setting the paper(s) equal emphasis should be given to physics and chemistry.

THE SYLLABUS

STANDARD 8

The main parts of the syllabus are italicised. Those portions not italicised are elaborations and limitations of the syllabus and, as such, form part of the syllabus.

It is not intended that the subject-matter in the Standard 8 syllabus shall be examined in the final examination at the end of Standard 10, unless this matter is repeated in the Standard 9 and the Standard 10 syllabuses or is used in developing further concepts.

1. LIGHT

1.1 *Light transfers energy*

Mention the effect of light on photographic film.
Show that an electric current is set up when light falls on a photo-electric cell, e.g. exposure meter.
Mention photosynthesis.

(D) (1) Show the effect of light on a photo-cell.

1.2 *How light travels*

1.2.1 *Rectilinear propagation of light*

Light rays travel **ALONG** straight lines.

(D) (2) Investigate the direction of propagation of light and the formation of shadows from a small source. 6

1.2.2 *Reflection*

Demonstrate reflection of a ray of light at a smooth plane surface. The laws of reflection. Formation of images in a plane mirror: position, size, nature. Point out that, although the laws are derived from consideration of reflection at a plane surface they are equally applicable to other shapes, e.g. curved mirrors. Compare with reflections of water waves. Mention diffuse reflection at rough surfaces.

(D) (3) (a) Investigate the reflection of light.
(b) Compare with reflection of water waves in a ripple tank.
(4) Investigate the formation of images in a plane mirror.

1.2.3 *Refraction*

The phenomenon of refraction. Refraction through transparent rectangular blocks. Compare with refraction of water waves. Real and apparent depths to be observed. Show by means of a diagram that this phenomenon can be explained in terms of refraction. Demonstrate total internal reflection. The critical angle.

(5) (a) Investigate the refraction of light through a rectangular glass block.
(b) Compare with the refraction of water waves in a ripple tank.
(D) (6) Observe apparent depths in water.
(D) (7) Observe total reflection.

1.2.3.1 Prisms

Passage of a ray of light through a prism to show refraction and total internal reflection.

Mention some uses of total internal reflecting prisms.

Investigate the dispersion of white light by a prism by showing the formation of the visible spectrum. Use the spectrum to show that the colour of objects is due to selective absorption of constituent colours of white light.

1.2.3.2 Lenses

Refraction through converging and diverging lenses.

Position, nature and size of image to be determined experimentally in the case of the converging lens.

Graphical constructions of ray diagrams for both types of lenses and the introduction of the terms principal axis, optical centre, focal point and focal length.

Magnification as $\frac{\text{height of image}}{\text{height of object}}$ and equal to $\frac{\text{distance of image}}{\text{distance of object}}$

Compare the camera and eye as instruments using light.

Mention the uses of lenses, e.g. magnifying glass, simple compound microscope, simple astronomical telescope.

2. SOUND

2.1 Production of sound

Sound is produced by vibrating objects.

2.2 Transmission of sound

Investigate transmission of sound through air, liquid, solid.

Stress that sound requires a material medium. Sound is transmitted as a wave through a medium; mention some properties of sound as evidence, e.g. reflection, refraction. Energy is transmitted by sound waves. Sound waves are longitudinal waves.

- (8) Investigate the path of a ray of light through a triangular glass prism.
- (9) Investigate the dispersion of white light through a 60°-prism by showing the formation of a visible spectrum.

(D) (10) Investigate reflection of light by coloured objects.

(D) (11) Investigate refraction of light by curved surfaces.

(D) (12) Investigate the formation of images by a convex lens. (The ray box is recommended for experiments on light.)

(D) (13) Investigate how sound is produced.

(D) (14) Investigate the propagation of sound through different media.

(D) (15) Investigate the transfer of energy by sound waves.

2.3 *Characteristics of sound*

2.3.1 *Speed of sound*

Determination of approximate speed of sound in air by direct measurement. Recall the relationship $v = f\lambda$ or $v = \nu\lambda$ for waves.

(16) Measurement of the speed of sound.

2.3.2 *Reflection of sound*

Angle of reflection is equal to the angle of incidence.
Echoes.

(17) Investigate reflection of sound waves.

Mention also refraction of sound, e.g. by gas lenses.

2.4 *Sound and the ear*

2.4.1 *Loudness and pitch*

Loudness depends on amplitude of the vibration.
Pitch depends on the frequency of the vibration.

(D) (18) Investigate the properties of vibration which determines the loudness and pitch of a note.

2.4.2 *Noise and musical note*

Noise is produced by irregular vibrations, a musical note by regular vibrations. Quality and "wave form": "wave forms" of pure note, musical note and noise.

3. HEAT, WORK AND INTERNAL ENERGY.

3.1 *Effects of temperature change*

Refer to changes in colour, size and phase. A rise in the temperature of a gas at constant volume causes an increase in pressure. The three phases of matter in terms of the particle model.

(19) Investigate the temperature change and/or change in phase caused by heat transfer.

3.2 *Heat—a form of energy*

Define "heat" as energy which is transferred from a body at a higher temperature to a body at a lower temperature.
The term "heat" applies only to the process of energy transfer. Before and after the transfer process, the energy is not called heat. Heat transfer to or from body leads to a change in temperature and/or to a change in phase.

4. ELECTRICITY

Brief revision of Standard 7 work on series and parallel circuits and cells.

4.1 *Measuring electrical quantities*

4.1.1 *Current*

Concept of current as rate of flow of charge.
Ammeter as instrument calibrated to record rate of flow of charge.
The unit is called the ampere (A).
The coulomb (C) as the quantity of charge passing any cross-section of a conductor in 1 second when the current is 1 ampere.

4.1.2 *Potential difference (electrical)*

Concepts of potential difference between two points in a circuit as a quantity which tells us how much energy is transferred when a unit charge moves from one point to the other.
The voltmeter is calibrated to measure potential differences in volts (V).
The volt considered as one joule per coulomb.

4.1.3 *Resistance*

Resistance as the ratio of potential difference to current.
The ohm (Ω), the unit of resistance.

Investigate the relationship $\frac{V}{I}$ for varying potential differences across a metallic conductor.

(22) The use of an ammeter and a voltmeter in a circuit to investigate

the relationship $\frac{V}{I}$ for different potential differences across a metallic conductor.

4.1.4 Emf and internal resistance of a cell

The cell considered merely as a device which provides electrical energy.

Emf considered only as the ability of the cell to give electrical energy to a given charge passing through the cell. It is expressed in volts. An approximate value is given by the reading on a voltmeter connected across the terminals of the cell when there is no additional external circuit.

Emf of cells in series.

A cell has internal resistance.

4.2 *Effects of current*

4.2.1 *Rise in temperature*

Brief revision of the rise in temperature when a current passes through a conductor. Stress that there is a transfer of energy in this case.

Discuss examples of the use of this effect in everyday life.

Use the ammeter and voltmeter readings to find the resistance of a piece of resistance wire when the potential difference is low (wire cold) and when the potential difference is high (wire red hot). Note that the resistance of a metallic conductor changes with temperature.

4.2.2 *Magnetic effects*

Demonstrate the magnetic field of a current in a straight conductor by using iron filings as well as compasses.

Demonstrate the field of a circular coil.

Demonstrate the field of a solenoid.

“Hard” and “soft” magnetic materials (retentivity); make an electromagnet.

Discuss the d.c. electric bell.

Demonstrate that a current-bearing wire in a magnetic field can experience a force.

Mention that this is the basic principle of ammeters, voltmeters and electric motors.

(D) (23) Investigate the effect of temperature on the resistance of a conductor.

(D) (24) Investigate the magnetic field which is a result of
(a) a current in a straight conductor;
(b) a current in a circular conductor; and
(c) a current in a solenoid.

(D) (25) Demonstrate the mechanical force on a current-carrying conductor in a magnetic field.

4.3 *Electromagnetic induction*

Induction of a current in a coil by

- (a) moving a magnet in the vicinity of a coil;
- (b) moving a coil in the field of a magnet; and
- (c) changing the current in a neighbouring coil.

In (a) and (b) note the effect on the galvanometer reading of the speed of motion, the strength of the magnet and the number of turns in the coil and in (c) note the effect of soft iron core on the induced current. Demonstrate the principle of the transformer. The simple dynamo. Explain its working in terms of the observed effects in the introductory experiments.

5. ATOMIC STRUCTURE

5.1 *The nuclear atom*

A BRIEF survey of the development of the model of the atom from a particle to a nuclear atom. Introduce terms nucleons, protons and neutrons; the latter simply as particles of approximately equal mass, one with a positive charge and one neutral. The mass of the proton taken as 1 u, mass of the neutron taken as 1 u. The number of protons in the nucleus determines the magnitude of the nuclear charge; this number is the atomic number of the atom of the element. Show that the elements are arranged on the Periodic Table in sequence of their atomic numbers.

Mass number.

Relative atomic mass.

- (26) Investigate the induction of a current by means of
 - (a) a magnetic field that moves with respect to a coil;
 - (b) a varying magnetic field by switching a current on and off; and
 - (D) (c) a varying magnetic field by using a.c.

5.1.1 *The neutral atom*

Atoms of elements are electrically neutral, therefore, in the atom there are as many negatively charged particles as there are protons in the nucleus. The negatively charged particles are called electrons. If an atom loses an electron, it becomes positively charged; if it gains an electron, it becomes negatively charged.

$$\text{Mass of electron} = \frac{1}{1840}u$$

Hence the mass of an atom is almost entirely the mass of the nucleus.

Mass number—the number of nucleons in the nucleus.

5.1.2 *Electronic structure*

Electrons are found in the space surrounding the nucleus. Electrons do not all have the same energy and the regions in space in which they are most likely to be found are specified by the energy of the electrons.

Electrons can have only certain specified energies: they occupy definite energy levels which are named "energy level 1", "energy level 2", etc.

The spaces to which the electrons are mainly confined are called "orbitals". Each energy level has a specific number of orbitals.

At this stage limit the discussion to four energy levels: 1, 2, 3 and 4 and s- and p-orbitals.

5.1.3 *The energy level diagram ("aufbau")*

Introduce the energy level diagram as a convenient way of representing both the energy levels and the orbitals associated with each level.

Discuss the "filling" of the orbitals with electrons for the elements of atomic numbers 1 to 20. (At this stage the "filling" is to be done by "rule of thumb" only.) Draw attention to the periodicity of the outer electronic structure of these twenty elements.

5.2 *How atoms combine*

Refer to the energy level diagrams of the elements already considered and point out the electrons in the highest energy level. As atoms come together to combine, it is reasonable to suppose that the first contact will be between the outermost electrons.

5.2.1 *The covalent bond*

The covalent bond CONCEPT: sharing pairs of electrons. Molecules are formed.

5.2.2 *The ionic bond*

The ionic bond CONCEPT: "transfer" of electrons resulting in ions and electrostatic attraction between ions.

5.2.3 *"Valency"*

The valency of an atom IN A COMPOUND related to the number of outer electrons.

Show how the "normal" valency of an element can be obtained from the number of the group of the Periodic Table in which it is found.

The charge on the ions of the elements can be found in the same way.

Build formulae of binary compounds using the Periodic Table to provide the "valency".

6. **CHEMICAL REACTIONS**

From this point in the syllabus balanced equations are required for all reactions studied, and chemical names are required for all substances encountered.

Relate in moles, the amount of each substance, involved to the equation coefficients in the balanced equation.

Simple calculations based on balanced equations should be done throughout the Chemistry Syllabus. (No volumetric calculations in 7.2 and 7.3.)

6.1 *Chemical reactivity of the metals with respect to the following*

6.1.1 *Oxygen*

Burn lithium, sodium, potassium, calcium, magnesium, iron, aluminium, zinc and copper in oxygen.

Note the intensity of the flame.

Note the alkalinity of water solutions of oxides of metals (universal indicator paper).

Heat copper oxides (CuO), magnesium oxide, lead oxide (PbO₂) and mercury oxide (HgO). Note those giving off oxygen and the ease with which the oxygen is produced.

- (D) (27) (a) Investigate the reactions and flame colours when Li, Na, K, Ca, Mg, Al, Fe, Zn and Cu burn in oxygen.
(b) Compare the alkalinity of the aqueous solutions of the oxides in (a) by using universal indicator.

- (D) (28) Compare the relative ease with which oxygen is liberated from CuO, MgO, PbO₂ and HgO on heating.

6.1.2 *Water (steam included)*

Reaction of lithium, sodium, potassium, calcium, magnesium, iron and copper. Note the ease with which elements release hydrogen. (Cold water, hot water, steam.) From the evidence collected, arrange the metals in a rough activity series.

Draw attention to the similarity of properties of Group I metals, the alkali metals.

- (D) (29) Investigate the comparative reaction rate of Li, K, Na, Ca, Mg, Fe and Cu with cold water.

- (30) Investigate the comparative reaction rate of Ca, Mg, Fe and Cu with boiling water.

- (D) (31) Investigate the reaction of heated magnesium powder, iron filings and copper turnings with steam.

6.1.3 *Solutions of metal salts*

Investigate the addition of each of iron, zinc, aluminium and copper to solutions of salts of the other metals.

Relate the reactivities to the position of the elements in the Activity Series.

- (32) Investigate the reaction of the metals Al, Zn, Fe and Cu on solutions of MgSO₄, ZnSO₄, FeSO₄, Pb(NO₃)₂, CuSO₄ and NaCl.

6.2 *Reactions of non-metals*

6.2.1 *Carbon, phosphorus and sulphur*

Limited to the reaction of each with oxygen. Note the acidity of water solutions of the oxides. (Universal indicator paper.)

Carbonic acid and sulphurous acid as solutions of CO₂ and SO₂ respectively.

- (D) (33) Investigate the combustion of C, S and P in oxygen and determine the approximate acidity of aqueous solutions of the oxides with universal indicator.

6.2.2 Halogens

Demonstrate the reaction of iodine with sodium and with magnesium.

Introduce the term oxidation in terms of electron transfer.

Demonstrate the displacement of bromine and iodine from bromides and iodides by chlorine water. The colours of bromine and iodine in CCl_4 or CS_2 .

Demonstrate the displacement of iodine from iodides by bromine water.

Relate displacement reactions to the position of the halogens in Group VII.

7. ACIDS, BASES AND SALTS

7.1 Properties of acids and alkalis (soluble bases)

Acid: sharp, sour taste; reaction with metal oxide and carbonate. Change of colour of indicator. Produces $\text{H}^+(\text{aq})$ ions in water solution.

Alkali: soapy feeling; change of colour of indicator; reaction with acid.

Produces OH^- ions in water solution.

Give formulae of common acids (HCl , H_2SO_4 , HNO_3 , H_2CO_3) and alkalis (NaOH , KOH , NH_4OH), their anions and the charge on the anions.

Collect information regarding the acidity or alkalinity of the water solutions of the oxides treated in 6.1 and 6.2.

Draw attention to the change in acidity or alkalinity for the oxides of the elements in Period 3.

Introduce the terms basic oxide and acidic oxide.

7.2 Neutralisation

Carry out neutralisation of acid with base using fairly concentrated solutions. Note that heat is evolved, i.e. energy given out. Using information of 7.1, work out ionic equations for some acid alkali neutralisation reactions and draw attention to the overall reaction as being $\text{H}^+ + \text{OH}^- \rightarrow \text{H}_2\text{O}$.

(34) Investigate the reactions of iodine with sodium and with magnesium.

(35) Investigate the reactions of

- (a) solutions of KBr and KI with Cl_2 -water, and
- (b) a solution of KI with Br_2 -water.

(36) Investigate the reactions (or effects) of dilute HCl , H_2SO_4 and HNO_3 on

- (a) colour of indicators;
- (b) metals: Zn , Fe , Mg (HNO_3 excluded);
- (c) metal oxides: CuO , MgO ; and
- (d) carbonates: Na_2CO_3 , CaCO_3 powder.

(37) Investigate the reactions (or effects) of dilute solutions of NaOH , KOH and NH_4OH in the following cases:

- (a) soapy feeling;
- (b) on indicators used in 36 (a); and
- (c) on dilute H_2SO_4 .

(38) Investigate the neutralisation of a fairly concentrated acid solution with an alkali (e.g. HNO_3 and KOH) with special reference to

- (a) temperature change;
- (b) gradual change in acidity;
- (c) end-point; and
- (d) products formed and recovery of salts.

7.3

Preparation of salts

Limit to acid + alkali; acid + carbonate; acid + metal; acid + metal oxide.

Brief revision of methods of obtaining crystals from solutions as done in Junior Secondary Science.

Calculations of percentage composition of a few of the salts produced.

8.

CHEMICAL REACTIONS AND ELECTRICITY

8.1

Evidence of existence of ions in solutions

Examine ionic salt crystals (solid); they do not conduct electricity. Examine a number of solutions and liquids and list those which conduct electricity and those which do not. Those which conduct are solutions of acids, bases and salts. These solutions contain ions.

8.2

Electrolysis

Electrolysis of a melt of an ionic compound with inert electrodes, e.g. lead bromide or lead iodide. Electrolysis of concentrated solution of an ionic compound with inert electrodes, e.g. CuCl_2 solution.

In both cases observe evidence of conduction of electricity and of chemical change.

Note the electrode at which the metal appears and at which the non-metal appears. Note the respective signs of the source terminals connected to these electrodes.

Discuss the model of ions moving to the two electrodes inside the electrolytic cell and of electrons moving through the external circuit.

Stress transformation of electrical energy into chemical energy.

Define oxidation and reduction in terms of loss or gain of electrons. Define anode as the electrode where oxidation occurs and the cathode as the electrode where reduction takes place.

8.3

Reactions producing electrical energy

Demonstrate establishment of potential difference between the electrodes of a simple cell. Point out transformation of chemical energy into electrical energy.

- (39) Preparation of NaCl crystals by neutralisation of NaOH and HCl.
(40) Preparation of MgSO_4 crystals by adding MgCO_3 to H_2SO_4 .
(41) Preparation of CuSO_4 crystals by adding CuO to H_2SO_4 .
(42) Preparation of FeSO_4 crystals by reaction of H_2SO_4 on Fe.

- (43) Investigate electrical conduction of

- (a) dry NaCl crystals and CuSO_4 crystals;
(b) distilled water;
(c) solutions of acids, alkalis, salts;
(d) paraffin, alcohol; and
(e) solutions of sugar in water and naphthalene in alcohol.

- (D) (44) Electrolysis of

- (a) a melt (PbBr_2 or PbI_2), and
(b) concentrated CuCl_2 solution with C-electrodes

- (D) (45) Demonstrate the production of potential difference in a simple cell, e.g. Zn rod and Cu plate in a dilute electrolyte.

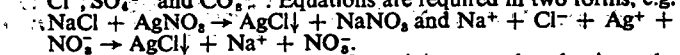
18

9. REACTIONS INVOLVING IONS

Reactions between aqueous salt solutions and the formation of precipitates (if any).

Limit the above reactions to salts of the metals of Group I and Group II and the anions Cl^- , Br^- , I^- , SO_4^{2-} , CO_3^{2-} , NO_3^- .

Tests should be developed, out of these reactions, for the anions Cl^- , SO_4^{2-} and CO_3^{2-} . Equations are required in two forms, e.g.



Calculations of the amount of precipitate produced, given the mass of one reactant and excess of the second, plus the relative atomic masses of the elements.

Calculations of the amount of precipitate given non-equivalent masses of the two reactants, plus the relative atomic masses of the elements.

STANDARD 9

The main parts of the syllabus are italicised. Those portions not italicised are elaborations and limitations of the syllabus and, as such, form part of the syllabus.

The subject-matter of the work in Standard 9 shall be examined in the final examination at the end of Standard 10.

1. VECTORS

1.1 *Displacement*

Displacement as a change of position in space.

The graphical representation of displacement.

The resultant of two or more successive displacements as a single displacement representing the same change of position as the two (or more) displacements together.

Graphical determination of the resultant of two or more displacements: the triangle and parallelogram constructions for two displacements; the polygon construction for more than two displacements. A closed figure implies zero displacement (zero resultant).

(46) In the following investigate reactions where ions are involved:

(a) A dilute solution of AgNO_3 with aqueous solutions of NaCl , CaCl_2 and NaNO_3 .

(b) A dilute solution of BaCl_2 with aqueous solutions of MgSO_4 , Na_2SO_4 and $\text{Ca}(\text{NO}_3)_2$.

(c) A solution of Na_2CO_3 with aqueous solutions of MgSO_4 , CaCl_2 and KCl .

(d) Dilute solutions of

(i) AgNO_3 with solutions of KCl , KBr , KI , and

(ii) chlorine water with solutions of KBr and KI .

4.2 *Force between charges*

[Coulomb's discovery that force between point charges is inversely proportional to the square of the distance between them:

$$F \propto \frac{1}{r^2}$$

Sharing of charges between identical conductors. The discovery that force between charges is directly proportional to the product of the charges.

$$F \propto Q_1 Q_2$$

Coulomb's Law in the form $F \propto \frac{Q_1 Q_2}{r^2}$

$$\therefore F = k \frac{Q_1 Q_2}{r^2} \text{ where } k = 9 \times 10^9 \text{ N.m}^2.\text{C}^{-2}.$$

4.3

Calculations limited to the force between two point charges.

Electric fields

The concept of electric field.

Lines of field for a single point source; two point sources; around a sphere and between parallel plates. (Plates large compared with separation.)

A charge in an electric field experiences a force: field strength (intensity as force/unit charge.)

Work done in moving charges in electric fields.

Potential energy of charge in an electrostatic field.

Potential difference (in volts) between points in a field in terms of work done (in joules)

charge moved (in coulombs)

The volt considered as joule/coulomb.

Quantitative treatment of the field between parallel plates.

$$\text{Strength of field } (E) = \frac{V}{d}$$

(Calculations limited to cases of UNIFORM fields.)

- (D) (11) (a) Investigation of the relationship between the forces exerted on each other by two charged objects and the distance between them (charge constant).
 (b) Investigation of the relationship between the magnitude of the charges and the forces on two objects (distance between them constant).]

- (D) (12) Investigation of the pattern of the electric field lines
 (a) around a single point charge;
 (b) around two point sources;
 (c) around a charged sphere; and
 (d) between two oppositely charged parallel plates.

5.4

Resistance and Ohm's law

Revise resistance in terms of potential difference and current.

The definition of the ohm. Ohm's law.

Deduce equivalent values for resistors (a) in series (b) in parallel.

Simple calculations

[Conversion of a galvanometer into an ammeter and into a voltmeter (calculations not required in the final examination)]

Mention non-ohmic conductors.

5.5

Heating effect

Point out that "heating" does not mean that the resistor receives heat but that its temperature increases as a result of electrical energy being converted into internal (thermal) energy.

Energy transferred to the conductor (W) = I^2Rt . Show that the energy transferred is proportional to I^2 , R and to t .

Revise power as work done per unit time, unit watt (W) ($J.s^{-1}$).

The volt defined as 1 watt per ampere.

Simple calculations.

[Emf (E) now considered as the rate of supply of energy per unit

current. $I = \frac{E}{R + r}$ for a simple direct current circuit consisting of

a source, with an internal resistance (r), and an external resistance (R).]

5.6

Alternating current

The difference between direct current and alternating current in terms of direction of flow of charge.

The advantages of high voltage and low current for long distance transmission.

Revise the transformer.

The function of the transformer in a.c. transmission.

(D) (16) Investigation of the relationship between the quantity of work done in a resistor and

(a) the time of current flow (current and resistance constant);

(b) the strength of the current (resistance and time constant);

(c) the resistance (time and current constant)

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6. THERMIONIC EMISSION

The phenomenon of thermionic emission and its application in the vacuum tube and the cathode ray tube. (Diode only.)

7. LIGHT

7.1 *Diffraction and interference*

Revise previous work with waves to revise terminology and relationship $v = f\lambda$ or $v = \nu\lambda$.

The principle of superposition of waves.

Standing waves.

Demonstrate diffraction and interference of water waves.

Observe diffraction of light by single slit.

Observe interference of light using double slit.

Point out that diffraction effects are actually special examples of interference.

By discussion show that only the wave theory can explain interference effects.

The above evidence suggests that light has wave properties.

Demonstrate polarisation and extinction of a transverse wave on a string using two slits. (This is NOT an analogue for polarisation of light.)

Demonstrate the polarisation of light by two crossed polaroids.

This suggests that light waves are transverse.

7.2 *Colour of light*

Revise work on the spectrum of light.

Mention line spectra.

The colour of light associated with the frequency of light waves.

Light waves of all frequencies have the same speed in vacuum but different speeds in material media.

(17) Observation of interference

(a) of light using a double slit, and

(b) of water waves using a ripple tank.

(18) Observation of diffraction

(a) of light using a single slit, and

(b) of water waves using a ripple tank.

(D) (19) Demonstration of theory of polarisation and extinction by using

(a) two polaroid plates, and

(b) two slits and a vibrating string.

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8. ELECTROMAGNETIC WAVES AND LIGHT

8.1 *Electromagnetic waves*

[An elementary description of electromagnetic waves in terms of the electric and magnetic vectors. (Mechanism of propagation is not required.)]

Accelerated charged particles produce electromagnetic radiations. Mention Maxwell's prediction of the speed of electromagnetic waves.

8.2 *Light as an electromagnetic wave*

Evidence of interference and diffraction done in the previous section indicates that light has wave properties.

Polarisation indicates that light is a transverse wave.

The speed of light is the same as the speed of other electromagnetic waves predicted by Maxwell.

8.3 *The electromagnetic spectrum*

Mention the order of magnitude of the frequencies and the corresponding wavelengths in different parts of the electromagnetic spectrum and the names given to these parts of the spectrum. (For examination purposes, candidates will be expected to remember only that infra-red radiations have frequencies between those of radio waves and visible light and ultra-violet radiations have frequencies between those of visible light and X-radiations.)

9. PARTICLES, WAVES AND QUANTA

9.1 *Particle nature of electrons and photons*

Experimental evidence for electrons: deflection of an electron beam by magnetic and by electric fields.

Refer to Millikan's experiment.

[e/m for the electron found experimentally. (This is not to be examined in the final examination.)]

Experimental evidence for photons: elementary discussion of the photo-electric effect.

$$E = hf = h \frac{c}{\lambda}$$

Quantisation of energy.

(D) (20) Demonstration of deflection of an electron beam by
(a) an electric field, and
(b) a magnetic field.

[(D) (21) Determination of the value of $\frac{e}{m}$ for an electron.]

(D) (22) Investigation of the photo-electric effect of
(a) ultra-violet light by using a zinc plate and an electroscope, and
(b) visible light by using a photo-diode.

9.2 *Wave nature of electrons and photons*

Experimental evidence:

for electrons: electron diffraction (films and photographs)
for photons: interference and diffraction as already discussed.

9.3 *Quantisation of energy as an explanation for line spectra*

10. THE ATOMIC NUCLEUS

10.1 *Rutherford's alpha particle scattering experiment*

Outline of the experiment, the results and his deduction that the atom contains a massive nucleus carrying all the positive charge. His conclusion concerning the size of the nucleus in comparison with the size of the atom as a whole.

[10.2 *Radioactivity*

10.2.1 *Natural radioactivity*

Natural radioactive changes involve the emission of either alpha or beta particles with or without the emission of gamma rays. Examples of different types of disintegration and the effect of such on the atomic number and the mass number of the isotopes.

10.2.2 *Artificial radioactivity*

An elementary discussion of the production of artificial radio-isotopes by bombardment of the nucleus with particles. The value of some radio-isotopes, e.g. Carbon - 14 as a tracer in botany, and various radio-isotopes used as tracers in medicine and in industry.]

(In dealing with Section 10, the terms atomic number (Z), mass number (A) and isotopes will have to be revised. Also, it will be necessary to introduce the method of writing nuclear symbols,

e.g. ${}^{12}_{6}\text{C}$.)

(23) Observation of scintillations in a spintharoscope.

11. **ATOMIC STRUCTURE**

In working through this section the terms atomic number, relative atomic and molecular masses, atomic mass constant, mole, Avogadro constant, percentage composition and empirical formulae should be revised and expanded, where required.

11.1 *Models*

Revise and extend the concept of the atomic model from the single indivisible particle of Dalton to the modern orbital model. Rutherford's model of a nuclear atom with electrons revolving round the nucleus. The objection to this on the basis that radiation of energy by rotating (and hence accelerating) electrons would lead to the collapse of the atom.

Observation of the spectrum of hydrogen.

Line spectra as evidence of energy levels with special reference to the spectrum of hydrogen.

Bohr's concept of allowed energy levels.

Point out that the total energy of an electron in an atom is the sum of the potential and the kinetic energy.

Shortcomings of the Bohr model of the atom.

Introduce the concept of the probability of finding an electron in a particular region of space: the orbital model.

11.2 *Quantum numbers*

Mention the first three quantum numbers and their significance.

11.3 *Orbitals*

The shape, number and orientation of *s*- and *p*-orbitals. The number of *d*- and *f*-orbitals in each energy level.

11.3.1 *"Filling" the orbitals*

The energy level diagram ("Aufbau").

The spin concept and Pauli's exclusion principle.

Hund's rule.

The electronic configuration of the elements with atomic numbers 1 to 36, (to 20) for 5.6.

(24) Determination of Avogadro's constant by an electrolytic method.

(D) (25) (a) Observation of some of the Balmer lines of the hydrogen spectrum, and

(b) measurement of the approximate wavelengths of these lines by means of a transmission grating.

- 11.4 *Electronic structure and the Periodic Table*
s-Block, *p*-block and *d*-block (transition) elements.
Periodicity of electronic structure and atomic radius.
Briefly refer to the trends in physical (boiling and freezing points, atomic and ionic sizes) properties down a group and across a period.
Refer to some of the chemical experiments of Standard 8 and show that similarities in properties down a group, with specific reference to the main Groups I and VII, are accompanied by the same outer energy level electronic configuration and that variation in properties across a period is accompanied by changing electronic configurations.
Elementary treatment of ionisation energies and electronegativities. The periodicity of these properties. (For examination purposes, candidates will be required to apply these properties in explanation only.)
- 11.5 "Valency"
Refer to the combinations of atoms of elements considered in Standard 8 and relate (a) the Group number with the number of valency electrons, (b) valency = Group number or (8 - Group number).

STANDARD 10

The main parts of the syllabus are italicised. Those portions not italicised are elaborations and limitations of the syllabus and, as such, form part of the syllabus.

1. CHEMICAL BONDING

- 1.1 *The concept of "molecule"*
Attractive and repulsive forces between atoms. Lowering of energy in the formation of molecules from separate atoms.
The concept of "bonding" and the use of models to explain molecular formation.

1.2 *The covalent bond model*

Overlap and bonding in diatomic molecules: *s-s* overlap (H_2), *s-p* overlap (HCl) and *p-p* overlap (Cl_2).

Representation of bonding: orbital overlap, Lewis and Couper notation.

Mention the terms sigma- and pi-bonding as a means of describing head-on overlap of orbitals (e.g. in H_2 , HCl, Cl_2) and sideways overlap of orbitals (e.g. in C_2H_4 and N_2).

Dative or co-ordinate covalent bonds in the formation of NH_4^+ and H_3O^+ .

1.3 *Molecular Geometry*

The shapes of the following molecules illustrated with three-dimensional models:

H_2 , Cl_2 , $[CO_2]$, C_2H_4 , H_2O , CH_4 , NH_3 .

The introduction of hybridisation only as a means of explaining the observed geometry of CO_2 , C_2H_4 , H_2O , CH_4 and NH_3 .

1.4 *Polar covalent bond*

The electron distribution in some polar molecules, e.g. HCl and H_2O with reference to the electro-negativities of the combining atoms.

1.5 *The ionic bond*

Revise the ionic bond concept. Lowering of energy in the formation of ionic crystals: lattice energy.

Partial ionic nature and partial covalent nature of bonds as indicated by relative electro-negativities of the combining atoms. Draw attention to the thermal stability of ionic crystals.

1.6 *The metallic bond*

Discuss those properties of metals which can be attributed to the metallic bond.

(D) (26) Construction of molecular models of H_2 , Cl_2 , $[CO_2]$, C_2H_4 , H_2O , NH_3 and CH_4 .

- 1.7 **Intermolecular forces**
 Elementary, qualitative discussion of van der Waal's forces and hydrogen bonding.
 Effect of hydrogen bonding on the physical properties of water.
 Intermolecular forces holding molecules in the liquid phase.
 Intermolecular forces responsible for crystallinity in molecular solids (ice).

2. **THREE PHASES (STATES) OF MATTER**

Brief résumé of the kinetic theory of matter as encountered in earlier studies.

2.1 **Gases**

2.1.1 **Ideal gas**

Boyle's law.

The pressure/temperature relationship [define a temperature scale from the pressure of a gas at the ice point and its pressure at the steam point (volume constant).]

The Kelvin scale based on the triple point of water.

$$\frac{p}{p_{\text{triple}}} = \frac{T}{273,16}$$

The Celsius scale in terms of the Kelvin scale.

The volume/temperature relationship (pressure constant).

The ideal gas law $pV = nRT$. ($pV = kT$ for S.G.)

[The kinetic theory leading to the relationship $pV = 1/3 Nm\bar{v}^2$ for an ideal gas. (Candidates will not be required to derive this equation in the examination.)]

Qualitative treatment of the relationship between mean kinetic energy of molecules and temperature. Distribution of kinetic energies at different temperatures.

Standard temperature and pressure.

2.1.2 **Non-ideal gases**

A brief treatment of deviations from the ideal gas behaviour.

Mention only (5G)

- (D) (27) Investigation of the relationship between pressure and the volume of a given mass of gas (temperature constant).
 (D) (28) Determination of the ratio of the pressure of a gas at the temperature of melting ice to its pressure at the boiling point of water (constant volume).

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2.1.3 *Simple example of gas law calculations*

2.2 *Liquids*

Intermolecular forces and the liquid state.
Briefly refer to liquid properties, change of liquid to vapour and change to solid. Refer to heat of fusion and heat of vaporisation of water.

2.3 *Solids*

2.3.1 *The concept of lattice*

2.3.2 *Bonding in solids*

Intermolecular forces and molecular solids.
Covalent bonds and network solids.
Comparison of structure of graphite and diamond and resulting difference in hardness and in conductivity.
Briefly mention delocalised electrons in graphite.
Ionic solids: the array of positive and negative ions and the properties of ionic crystals.
Metals.

2.4 *Phase equilibrium*

Qualitative treatment of phase equilibrium.
Vaporisation as a dynamic equilibrium.
Vapour pressure and boiling point.
Qualitative treatment of the effect of non-volatile dissolved substances on vapour pressure and on the boiling point of the solvent.

3. **SOLUTIONS**

The nature of a solution.
Intermolecular forces and the solubility of molecular, covalent and ionic compounds in non-polar and polar solvents.
Ion formation: (a) dissociation of ionic compounds, (b) polar covalent molecules (HCl, NH₃) dissolved in water.
Hydration [and hydration energy.]
Concentration of solutions (mol. dm⁻³).
Preparation of standard solutions.

(D) (29) Investigation of the effect of a non-volatile dissolved substance on boiling point of the solvent.

(30) Preparation of a standard solution of oxalic acid.

5.2.2 *Randomness and the equilibrium condition*
Tendency towards randomness and its importance in controlling certain reactions.
Spontaneous endothermic reactions as illustrative of the effects of the randomness factor.

5.2.3 *The equilibrium condition*
A compromise between the energy and the randomness factors.]

5.3 *Solubility equilibrium*
The dynamic nature of solubility equilibrium.
The energy and randomness factors in the solubility process.
The solubility product in the form $K_{sp} = [A^+]^a[B^-]^b$ for
 $A_aB_b \rightleftharpoons aA^+ + bB^-$.
Simple calculations to determine whether a precipitate will form.]
The effect of temperature on the solubility equilibrium.

5.4 *Acids and bases*
Near complete ionisation (HCl) and partial ionisation (acetic acid) to give ions in solution.

5.4.1 *Ionisation of water*
 K_w —its value and meaning.
[H^+] (or $[H_3O^+]$) in solutions of HCl and $[OH^-]$ in solutions of NaOH.

5.4.2 *Models for acid and base*
Release of and combination with hydrogen ions.
Proton transfer or proton donor-acceptor concept.
Protolytic reactions.

5.4.3 *Acid-base titrations*
Neutralisation reactions and an introduction to acid-base titrations.
Calculations of concentrations in a few selected examples.
Standardisation of an acid and a base.

(36) Separation of cations by formation of insoluble salts, e.g. Ag^+ , Cu^{2+} and Mg^{2+} .

(37) Standardisation of a dilute solution of a base using a standard solution of an acid and a suitable indicator, e.g. sodium hydroxide and oxalic acid with phenolphthalein.
(38) Standardisation of a dilute solution of an acid (e.g. hydrochloric acid) using the base of (37) and a suitable indicator.

5.4.4 *pH*

The pH concept and the pH scale.
The importance of hydrogen ion concentration in aqueous solutions.
The relative strengths of acids and bases in aqueous solutions.

5.4.5 *The trends only in the acidic and basic character of the hydroxides of the elements of period 3.*

6. ELECTRO-CHEMICAL CELLS

The Cu-Zn cell and its chemistry.
The half-cell or half-reaction; electrons as part of the reaction.
The combination of two half-cell reactions to give the overall cell reaction.
Oxidation and reduction in terms of electrons being released or accepted.

Half-cell voltages and the "competition" for electrons.

Selection of a standard half-cell.

Standard electrode potentials for half-reactions.

Use of standard electrode potentials for predicting the cell reaction and the emf.

An elementary discussion of corrosion and its prevention.

7. OXIDATION-REDUCTION

Oxidation-reduction reactions explained in terms of electron transfer.
The use of half-reactions to balance oxidation-reduction equations.
Oxidation numbers.

The use of oxidation numbers to balance redox equations and to identify the oxidising and reducing agents.

7.1 *The trends in oxidising and reducing properties of the elements down the main groups I and VII and across period 3.*

The oxidising and reducing properties of a few selected transition elements, e.g. Mn, Fe, Cu, Zn.

(39) Comparison of the relative acid-base strength of the hydroxides of period 3 elements.

(40) Investigation of

(a) a metal displacement reaction, e.g. zinc and copper sulphate solution, and

(b) reaction between metal atoms and metal ions when they are not in contact, e.g. zinc-copper cell.

(41) Investigation of the reducing ability of a few metals.

8. ORGANIC CHEMISTRY

Information has been gathered about the shapes of and the bonding in some organic compounds.

The work which follows is intended to co-ordinate the information and to indicate to a limited degree the place of organic chemistry in everyday life.

It is essential that, where possible, principles should be illustrated in the laboratory.

- 8.1 *What is organic chemistry?*
Definition of organic chemistry.
Sources of carbon and carbon compounds.
Constitution and unique multiplicity of organic compounds.
- 8.2 Structure
The structure of some organic compounds.
- 8.3 Nomenclature
Naming and classification of organic compounds with reference to functional groups.
- 8.4 *Some important classes of organic compounds*
- 8.4.1 *Hydrocarbons*
Alkanes: C_nH_{2n+2} , with chainlike structure (methane, ethane, propane and butane), and branched chains (methyl propane).
Alkenes, C_nH_{2n} (ethene)
Alkynes, C_nH_{2n-2} , (ethyne).
- 8.4.2 Halo-alkanes or alkyl halides, $C_nH_{2n+1}X$, where X is a halogen (chloro-methane, bromo-ethane)
- 8.4.3 Alcohols
 $C_nH_{2n+1}OH$, (R-OH), (methanol, ethanol, propan-1-ol and propan-2-ol).
- 8.4.4 Carboxylic acids
Carboxylic acids, $C_nH_{2n+1}COOH$, (methanoic and ethanoic acids). Carboxylic acid derivatives. Esters (methyl methanoate, methyl ethanoate, ethyl ethanoate).

- (42) Investigate the following reactions of a few selected organic compounds:
- (a) An alkane, e.g. cyclo hexane (C_6H_{12}), and an alkene, e.g. cyclo hexene (C_6H_{10}) with a solution of bromine in CCl_4 .
- (b) (i) An halo-alkane, e.g. bromo-ethane solution with silver nitrate solution.
(ii) An halo-alkane, e.g. bromo-ethane solution with sodium hydroxide solution and silver nitrate solution.
- (c) An alcohol, e.g. methanol or ethanol with acidified potassium permanganate or potassium dichromate solution.
- (d) An alcohol, e.g. ethanol with glacial methanoic acid.
- (43) Demonstrate the formation of a plastic, e.g. by adding a few crystals of benzoyl peroxide to methyl methacrylate (heated in a beaker of water) OR by adding a solution of sodium hydroxide and hexamethylene diamine to a solution of sebacyl chloride in carbon tetrachloride..

APPENDIX VIITEACHING METHOD OBSERVATION SCHEDULESchool: Date:Teacher: Standard:

| <u>METHOD</u> | | <u>FREQUENCY (Circle)</u> | | | | |
|---------------|--|---------------------------|-----|-----|-----|---|
| 1. | <u>Lecture methods</u> | | | | | |
| 1.1 | Lecture, using textbook and chalkboard | 0 | 1/4 | 1/2 | 3/4 | 1 |
| 1.2 | Lecture, using textbook and overhead/slide projector | 0 | 1/4 | 1/2 | 3/4 | 1 |
| 2. | <u>Discussion methods</u> | | | | | |
| 2.1 | Discussion, based on textbook | 0 | 1/4 | 1/2 | 3/4 | 1 |
| 2.2 | Discussion, based on experiment or demonstration | 0 | 1/4 | 1/2 | 3/4 | 1 |
| 2.3 | Discussion, pupil initiated | 0 | 1/4 | 1/2 | 3/4 | 1 |
| 3. | <u>Demonstration methods</u> | | | | | |
| 3.1 | Lesson (not discussion) based on demonstration | 0 | 1/4 | 1/2 | 3/4 | 1 |
| 3.2 | Demonstration integrated with lesson | 0 | 1/4 | 1/2 | 3/4 | 1 |
| 4. | <u>Activity methods</u> | | | | | |
| 4.1 | Lesson (not discussion) based on pupil experiments | 0 | 1/4 | 1/2 | 3/4 | 1 |
| 4.2 | Enquiry-discovery method | 0 | 1/4 | 1/2 | 3/4 | 1 |
| 4.3 | Auto-tutorial (self-study) methods | 0 | 1/4 | 1/2 | 3/4 | 1 |

APPENDIX VIII

FINAL EXAMINATION PAPERS

DEPARTMENT OF EDUCATION, CAPE OF GOOD HOPE: 1976 AND 1977

A. PHYSICAL SCIENCE (HIGHER GRADE)

NATUUR- EN SKEIKUNDE HG

79

PHYSICAL SCIENCE HG

1976

DEPARTEMENT VAN ONDERWYS
KAAP DIE GOEIE HOOP

DEPARTMENT OF EDUCATION
CAPE OF GOOD HOPE

SENIOR SERTIFIKAAT-EKSAMEN
SENIOR CERTIFICATE EXAMINATION

Skryf op die voor-buiteblad van u antwoordeboek, teenoor die woord "Vak" -

NATUUR- EN SKEIKUNDE HOËR GRAAD

Write on the front cover of your answer-book, after the word "Subject" -

PHYSICAL SCIENCE HIGHER GRADE

Hierdie vraestel bestaan uit 33 bladsye

This examination paper consists of 33 pages

BLAAI OM ASSEBLIEF / PLEASE TURN OVER

PHYSICAL SCIENCE HIGHER GRADE

Three hours

Answer ALL the questions in SECTION A on the answer-sheet provided; answer any FOUR questions from SECTION B in your answer-book.

Consult the accompanying pamphlet with data where necessary.

SECTION A (COMPULSORY)

READ THE FOLLOWING INSTRUCTIONS CAREFULLY BEFORE ANSWERING THIS SECTION

1. Use the printed answer-sheet enclosed with your question paper to answer this section.
 2. Write your EXAMINATION NUMBER in the space indicated.
 3. Use a PENCIL only on your answer-sheet.
 4. In the case of a wrong answer, erase the pencil mark completely.
 5. Do not make any other marks on your answer-sheet. Any calculations or writing that are necessary in the answering of the multiple choice questions 1 to 20, should be done in the answer-book and must be clearly deleted with a diagonal line across the page.
 6. The calculations for questions 21 to 28 should be done on pages 2 and 3 of the answer-sheet.
 7. PLACE THE COMPLETED ANSWER-SHEET INSIDE YOUR ANSWER-BOOK.
- A. Five possible answers, indicated by (a), (b), (c), (d) and (e), are supplied with each question. Choose only that answer which in your opinion is the correct or best answer and fill in the appropriate block on your answer-sheet.

Example

QUESTION : The symbol for hydrogen is

(a) S (b) W (c) H (d) N (e) P

ANSWER :

(a) (b) (c) (d) (e)

(Use a PENCIL only for filling in the blocks. Each question has only one correct answer. If more than one block is filled in no marks will be given for that answer.)

PLEASE TURN OVER TO PAGE 5

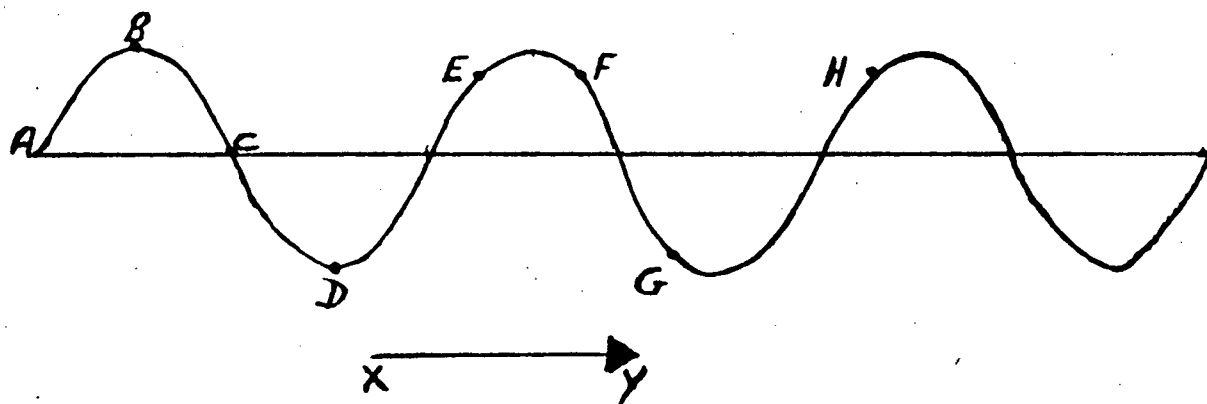
PHYSICAL SCIENCE HIGHER GRADE

1. The property of a wave motion which distinguishes a travelling wave from a stationary wave is

- (a) amplitude
 (b) direction of vibration
 (c) frequency of vibration
 (d) propagation of energy
 (e) wavelength.

(4)

Questions 2, 3 and 4 refer to the diagram below which shows the profile of a transverse wave



2. Two points which are in phase are

- (a) A and C
 (b) E and H
 (c) E and F
 (d) B and D
 (e) G and H.

(4)

3. The distance which represents one wavelength is

- (a) AC (b) BD (c) EH (d) EF (e) GH.

(4)

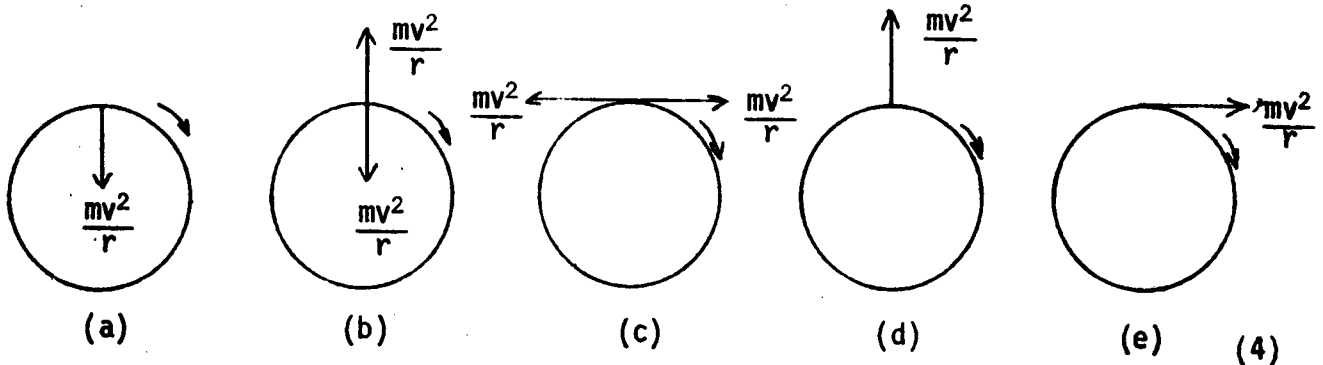
4. If the arrow XY represents the direction in which the energy is being propagated, the direction of the motion of point E at the instant shown is

- (a) ↓
 (b) ↑
 (c) →
 (d) ↘
 (e) ←

(4)

PHYSICAL SCIENCE HIGHER GRADE

5. The order of increasing frequency for the given waves in the electromagnetic spectrum is
- radio, visible light, infra-red, X-rays, ultra-violet
 - ultra-violet, X-rays, visible light, infra-red, radio
 - X-rays, ultra-violet, visible light, radio, infra-red
 - radio, infra-red, visible light, ultra-violet, X-rays
 - radio, infra-red, visible light, X-rays, ultra-violet. (4)
6. A satellite, mass m kg is in circular orbit, radius r m, with speed v m.s⁻¹. The diagram which best represents the force(s) acting on the satellite is



7. If a body in free fall is said to be 'weightless', each of the following may be said to be 'weightless' EXCEPT
- a satellite in earth orbit
 - a ball thrown upwards
 - a bullet fired horizontally from a gun
 - a boy jumping from the top of a wall
 - a man in a lift descending at 2 m.s⁻². (4)
8. The saturation current through a vacuum diode depends *only* on
- the potential difference between the anode and the cathode
 - the distance between the anode and the cathode
 - the material of the anode
 - the shape of the anode
 - the temperature of the cathode. (4)

PHYSICAL SCIENCE HIGHER GRADE

9. Below are three suggested ways by which the deflection of electrons in a cathode-ray tube may be varied:
- (i) Change the strength of the magnetic deflecting field
 - (ii) Change the potential difference across a pair of deflecting plates
 - (iii) Change the filament current
- Of the above ways, the *only* correct ones are
- (a) (i), (ii) and (iii)
 - (b) (i) and (ii)
 - (c) (iii)
 - (d) (i) and (iii)
 - (e) (ii) and (iii).
- (4)
10. A man stands in a lift which descends at a constant speed. If the push of the floor on the man is P and the pull of the earth on the man (his weight) is W , then the net force on the man is
- (a) slightly greater than W , vertically downwards
 - (b) slightly greater than P , vertically upwards
 - (c) zero
 - (d) a fraction of P , vertically upwards
 - (e) a fraction of W , vertically downwards.
- (4)
11. The number of grams of sodium that contains approximately 6×10^{22} atoms is
- (a) 23
 - (b) 1
 - (c) 230
 - (d) 2,3
 - (e) 6.
- (4)
12. The trend with regard to the changes in atomic radii in a period can best be understood by taking into account
- (a) repulsion between electrons
 - (b) the increasing nuclear charge
 - (c) the effect of Hund's rule
 - (d) the changing atomic mass
 - (e) changes in electronegativity.
- (4)
13. An example of s-p orbital overlapping can be found in
- (a) HCl
 - (b) Cl_2
 - (c) SO_2
 - (d) N_2
 - (e) H_2 .
- (4)

PHYSICAL SCIENCE HIGHER GRADE

14. The formation of the ammonium ion from ammonia illustrates
- a sigma-bond
 - dative bonding
 - a pi-bond
 - a double bond
 - sp hybridisation.
- (4)
15. The vapour pressure of a liquid
- depends on its boiling point
 - cannot change
 - can be lowered by adding a non-volatile solid
 - increases with decreasing temperature
 - is the same as the vapour pressure of all other liquids.
- (4)
16. Cathodic protection is a method of preventing iron corrosion by
- painting the metal
 - chromium plating
 - assisting oxidation of the metal
 - charging it negatively compared to its surroundings
 - galvanising the metal.
- (4)
17. In a reaction where ClO_3^- becomes Cl^- the oxidation number of chlorine
- decreases by 6
 - decreases by 4
 - increases by 3
 - is unchanged
 - decreases by 7.
- (4)
18.
$$\text{H} - \begin{array}{c} \text{H} \\ | \\ \text{C} \\ | \\ \text{H} \end{array} - \begin{array}{c} \text{H} \\ | \\ \text{C} \\ | \\ \text{H} \end{array} - \begin{array}{c} \text{H} \\ | \\ \text{C} \\ || \\ \text{O} \end{array} - \text{O} - \begin{array}{c} \text{H} \\ | \\ \text{C} \\ | \\ \text{H} \end{array} - \text{H}$$
- is the formula of
- an acid
 - an alcohol
 - an ester
 - an alkyne
 - a halo-alkane.
- (4)

PHYSICAL SCIENCE HIGHER GRADE

19. An element Y has two isotopes, which could be represented as
- (a) ${}_{8}^{17}\text{Y}$ and ${}_{9}^{17}\text{Y}$
- (b) ${}_{8}^{17}\text{Y}$ and ${}_{9}^{18}\text{Y}$
- (c) ${}_{8}^{17}\text{Y}$ and ${}_{16}^{33}\text{Y}$
- (d) ${}_{17}^{35}\text{Y}$ and ${}_{17}^{35}\text{Y}$
- (e) ${}_{17}^{35}\text{Y}$ and ${}_{17}^{36}\text{Y}$. (4)
20. Hydrogen bonds differ from other dipole-dipole forces in that they are
- (a) weaker, and exerted in all directions
- (b) weaker, due to the small size of the hydrogen atom
- (c) the same strength, but act through great distances
- (d) stronger, and exerted in all directions
- (e) stronger, due to the shorter distance over which they act. (4)
- B. Do the calculations for each of the questions 21 to 28 on pages 2 and 3 of your answer-sheet. Where applicable the appropriate formula should be written down with your calculation and the value for g be taken as $10 \text{ m}\cdot\text{s}^{-2}$.
21. Two point charges of $5 \mu\text{C}$ and $10 \mu\text{C}$ exert electrostatic forces of $1,8 \text{ N}$ on each other when in vacuum. Calculate the distance between the two point charges. (5)
22. A projectile is fired vertically downwards from a motionless balloon floating in the air. The projectile leaves the balloon at a velocity of $200 \text{ m}\cdot\text{s}^{-1}$ and strikes the ground at $300 \text{ m}\cdot\text{s}^{-1}$. Calculate the height from which the projectile was fired. (Ignore air friction and use $g = 10 \text{ m}\cdot\text{s}^{-2}$.) (4)
23. Waves with wavelength $0,2 \text{ m}$ travel a distance of 300 m in $1,5 \text{ s}$. Calculate the frequency of the waves. (5)
24. A force of $0,015 \text{ N}$ is required to move an electric charge of $50 \mu\text{C}$ between two points in a uniform electric field. If the potential difference between the two points is 90 V , calculate the distance between them. (6)

PHYSICAL SCIENCE HIGHER GRADE

25. What volume of CO_2 (measured at STP) would be produced if 40 g of calcium carbonate is strongly heated? (5)
26. Calculate the volume (in m^3) of 10 moles of nitrogen at a pressure of 200 kPa and a temperature of -33°C . (5)
27. For the reaction
- $$2 \text{CO} (\text{g}) + \text{O}_2 (\text{g}) \rightleftharpoons 2 \text{CO}_2 (\text{g})$$
- the concentrations at a particular temperature are
- CO: 2,5 $\text{mol}\cdot\text{dm}^{-3}$
O₂: 2 $\text{mol}\cdot\text{dm}^{-3}$
CO₂: 9 $\text{mol}\cdot\text{dm}^{-3}$
- Calculate the equilibrium constant at that temperature. (5)
28. Calculate the volume of a 0,1 $\text{mol}\cdot\text{dm}^{-3}$ solution of sodium hydroxide required to neutralise 20 cm^3 of 0,2 $\text{mol}\cdot\text{dm}^{-3}$ sulphuric acid. (5)

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PLEASE TURN OVER TO PAGE 17

PHYSICAL SCIENCE HIGHER GRADESECTION B

Answer any FOUR questions. (Use $g = 10 \text{ m.s}^{-2}$ where necessary)

(VELOCITY; FORCE; VELOCITY-TIME GRAPH; PROJECTILE MOTION)

1. (a) Starting at A, a boy runs due north for 30 s at 5 m.s^{-1} to B and then due west for 20 s at 10 m.s^{-1} until he reaches C.

Calculate, using a rough drawing,

- (i) the displacement experienced by the boy
(ii) the average velocity of the boy. (18)

- (b) A car, mass 1 500 kg, runs straight into a wall at 12 m.s^{-1} . The car is brought to rest in 0,1 s. Calculate the force, assumed constant, which is exerted on the car during the impact. (8)

- (c) Starting from rest and accelerating uniformly along a straight section of a horizontal road, a car reaches a speed of 60 m.s^{-1} in 20 s. It maintains this speed for 30 s. The brakes are now applied evenly and the car is stopped after a further 10 s.

- (i) Draw a neat sketch of the velocity-time graph of the motion in your answer-book. (Time along the horizontal axis and velocity along the vertical axis).

(ii) Use your graph to determine

- (1) the uniform acceleration during the first 20 s
(2) the uniform acceleration during the last 10 s
(3) the total distance covered in 60 s. (24)

PHYSICAL SCIENCE HIGHER GRADE

- (d) A stone, mass 3 kg, is thrown horizontally from the top of a vertical cliff overlooking the sea. The speed with which it is thrown is 25 m.s^{-1} and it strikes the sea after 4 s. (Assume $g = 10 \text{ m.s}^{-2}$ and ignore air resistance).

Calculate

- (i) the height of the cliff above sea-level
- (ii) how far from the foot of the cliff the stone strikes the sea
- (iii) the total energy of the stone with respect to sea level at the instant it leaves the thrower's hand. (20) /70/

(CIRCULAR MOTION; RECTANGULAR COMPONENTS OF FORCES; CURRENT ELECTRICITY)

2. (a) A satellite, mass 50 kg, is in a circular orbit with radius 6 670 km, measured from the earth's centre.

- (i) Write down an expression for the gravitational force of attraction between the earth and the satellite. Briefly state the meaning of each symbol used in the expression.
- (ii) Write down an expression for the centripetal force on the satellite. Briefly state the meaning of every symbol not already mentioned in (i).
- (iii) By using the expressions you have written down in (i) and (ii), calculate the speed of the satellite. (18)

- (b) Two forces, A and B, act on a point O:

A = 300 N in a direction $N 30^\circ E$

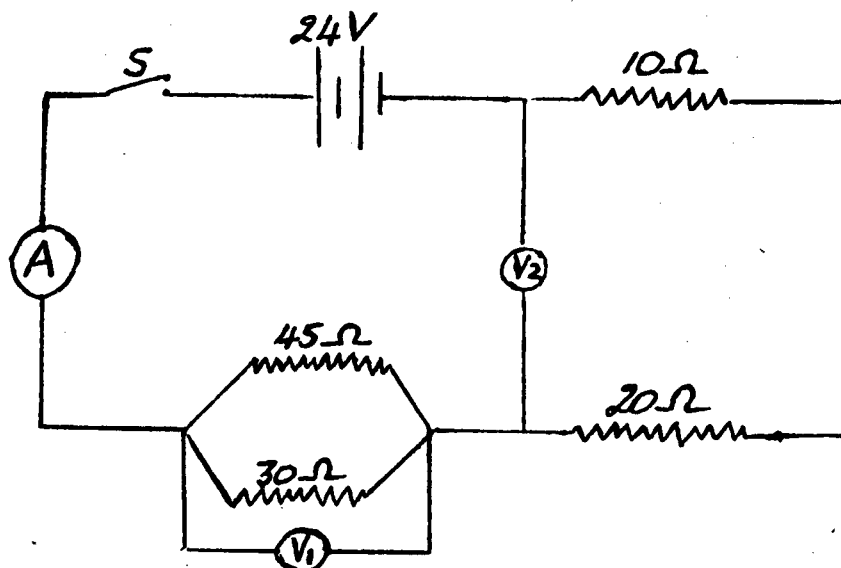
B = 200 N in a direction $E 30^\circ N$

Calculate, using a rough drawing,

- (i) the components ON_A and OE_A of force A in the northerly and easterly directions respectively

PHYSICAL SCIENCE HIGHER GRADE

- (ii) the components of the resultant force (ON_R and OE_R in the northerly and easterly directions respectively) if the components of force B are 100 N due north and 173,2 N due east. (26)
- (c) What is the magnitude and what is the direction of a force which has components 400 N due north and 300 N due east? (10)
- (d) A diagram of an electric circuit is given below:



The 24 V supply has negligible internal resistance.

Calculate

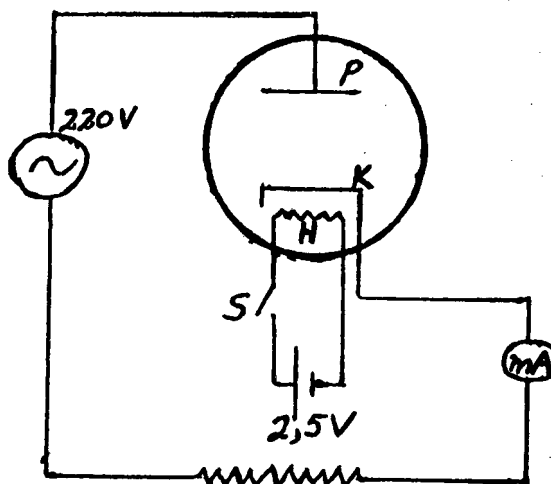
- (i) the equivalent resistance of the parallel resistors
- (ii) the reading on the ammeter A when switch S is closed
- (iii) the readings on voltmeters V_1 and V_2 when switch S is closed.

(16) /70/

PHYSICAL SCIENCE HIGHER GRADE

(MAGNETIC FIELD IN A SOLENOID; DIODE; TRANSFORMER; WAVES)

3. (a) A current-element at right angles to the magnetic field inside a current-carrying solenoid experiences a force.
- (i) On which quantities does the magnitude of the force on the current-element depend?
 - (ii) What is the name given to the unit of *magnetic induction*?
 - (iii) In an experiment to determine the magnitude of the magnetic field inside a current-carrying solenoid, a downward force of $3,0 \times 10^{-4}$ N is exerted on an element, 50 mm long, carrying a current of 2 A. Calculate
 - (1) the magnitude of the magnetic field
 - (2) the mass of the object required to restore the equilibrium of the current balance.
- (21)
- (b) In the circuit diagram below, a diode is connected in series to a 220 V alternating current supply, a resistor R and a milli-ammeter mA. The element, H, of the diode is connected in series with a switch and a 2,5 V direct current supply.



- (i) What is the function of the diode in this circuit?
- (ii) Briefly explain the operation of this diode when switch S is closed.

PHYSICAL SCIENCE HIGHER GRADE

- (iii) In which direction does the conventional current flow in this circuit?
- (iv) Draw a rough graphic representation of this current versus time. (16)
- (c) When the current in the primary windings of a transformer is 15 A, the current in the secondary windings is 0,5 A.
- (i) What type of transformer is used here?
- (ii) Briefly explain how the transformer works.
- (iii) Calculate the potential difference across the secondary coil if the potential difference across the primary coil is 250 V. (18)
- (d) An electromagnetic wave has a frequency of 5×10^{14} Hz.
- Calculate
- (i) its period
- (ii) its wave-length
- (iii) the energy of its photons. (15)

/70/

(ATOMIC STRUCTURE; BONDING; SOLIDS; REACTION RATES; ACIDS)

4. (a) Vanadium is an element with $Z = 23$.
- (i) Write down its electron configuration using the s,p-notation.
- (ii) State how many valence electrons it possesses, name the orbital that contains these valence electrons, and describe its shape.
- (iii) If vanadium in its ground state combined with an element X, of valence = 1, what would be the formula of the compound? Explain your answer briefly.
- (iv) If the electron configuration is constructed according to the aufbau principle, write down the name of each quantum number, and state the value each would have for the last electron added to this atom. (26)

PHYSICAL SCIENCE HIGHER GRADE

- (b) Potassium fluoride is an ionic compound.
- (i) Describe how potassium in the gaseous phase combines with a fluorine atom, referring to each energy change involved.
 - (ii) On what basis could you predict that this will be an ionic bond? (12)
- (c) Diamond is an example of a macromolecular crystal.
- (i) Briefly describe the type of bond present in the crystal, and state the type of spatial arrangement in this crystal.
 - (ii) In what way does the structure of graphite differ from diamond? (10)
- (d) The activation energy of a reaction will influence the reaction.
- (i) What is meant by 'activation energy'?
 - (ii) What effect does a catalyst have on a reaction?
 - (iii) How does the catalyst achieve this effect? (10)
- (e) A dilute solution of hydrochloric acid is standardised using a solution of sodium hydroxide.
- (i) What is the name given to this type of chemical reaction?
 - (ii) Name the indicator you would use, and state its colour change.
 - (iii) Compare the pH of aqueous hydrochloric and oxalic acid solutions which have the same concentrations. (12)

/70/

(BONDING; GASES; SOLUTIONS; ELECTROCHEMICAL CELL)

5. (a) Methane forms when the orbitals of the carbon atom undergo sp^3 hybridisation.
- (i) Describe briefly how this hybridisation occurs, and comment on the shape of the resultant molecule.
 - (ii) In what ways does a molecule where sp^2 hybridisation occurs differ from this? (18)

PHYSICAL SCIENCE HIGHER GRADE

- (b) An experiment has been performed to show the relationship between the pressure of an ideal gas at the ice-point (freezing point) of water and its pressure at the steam-point (boiling point) of water (volume constant).
- (i) Draw a rough, labelled graph to illustrate this relationship.
 - (ii) How is the temperature scale defined from this experiment?
 - (iii) Write down the approximate values of the ice-point and the steam-point on the Kelvin scale.
 - (iv) What is meant by the triple point of water?
 - (v) Give the value of the triple point on the Celsius scale.
- (22)
- (c) A solution of sodium chloride in water will differ from a solution of hydrogen chloride in water.
- (i) Write an equation to show what happens to the sodium chloride in water.
 - (ii) What name is given to this process in (i)?
 - (iii) Write an equation to show what happens to the hydrogen chloride in water.
 - (iv) In what way does the phenomenon shown in the equation in (iii) differ from that shown in the equation in (i)?
- (13)
- (d) An electrochemical cell is set up with zinc and copper electrodes.
- (i) Write down the equation for the net reaction in the cell.
 - (ii) Which way do electrons flow in the external circuit?
 - (iii) Calculate the emf of this cell.
 - (iv) Explain the meaning of *standard electrode potential*.
 - (v) Zinc is the anode in this reaction. How could zinc become the cathode in an electrochemical cell?
- (17)

/70/

PHYSICAL SCIENCE HIGER GRADE

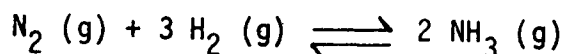
(ATOMIC STRUCTURE; EQUILIBRIUM; OXIDATION-REDUCTION; ORGANIC CHEMISTRY)

6. (a) A hydrogen discharge tube is observed through a diffraction grating while a high potential difference is applied across its ends.

- (i) What will be seen?
- (ii) Give the name of this series.
- (iii) Briefly describe the causes for what you have observed.
- (iv) For what reason is a high potential difference applied?

(17)

(b) The industrial manufacture of ammonia, which is exothermic, is given by the equation

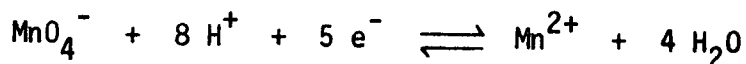
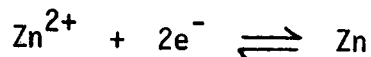


- (i) What is this process called?
- (ii) Briefly state Le Chatelier's Principle.
- (iii) What will the effect on the equilibrium be if:

- (1) the temperature is raised
- (2) the pressure is increased
- (3) a catalyst is added?

(15)

(c) The half-reactions as taken from Table 7 for the reaction between zinc and the permanganate ion are



- (i) State what an oxidising agent is, and name the oxidising agent for this reaction.
- (ii) Balance this equation, showing your working.
- (iii) What is the significance of the H^+ in the second half-reaction?
- (iv) MnO_4^- cannot be found independently. How is it usually obtained in the laboratory?
- (v) Why is this other ion mentioned in your answer in (iv) not included in the equation?

(20)

PHYSICAL SCIENCE HIGHER GRADE

- (d) The alkenes are a series of unsaturated hydrocarbons.
- (i) What is the meaning of *unsaturated*?
 - (ii) Write down the general formula of the alkenes.
 - (iii) Draw the structural formula of the simplest alkene, and name the alkene.
 - (iv) The difference between the reaction of an alkane (cyclohexane) and an alkene (cyclohexene) can easily be shown in laboratory. Briefly state what substances are used, and what is observed.

(18)
/70/

PHYSICAL SCIENCE HG

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NATUUR- EN SKEIKUNDE HG

1977

DEPARTMENT OF EDUCATION
CAPE OF GOOD HOPE
DEPARTEMENT VAN ONDERWYS
KAAP DIE GOEIE HOOP

SENIOR CERTIFICATE EXAMINATION
SENIOR SERTIFIKAAT-EKSAMEN

Write on the front cover of your answer-book, after the word "Subject" -

PHYSICAL SCIENCE HIGHER GRADE

Skryf op die voor-buiteblad van u antwoordeboek, teenoor die woord "Vak" -

NATUUR- EN SKEIKUNDE HOËR GRAAD

This examination paper consists of 35 pages
Hierdie vraestel bestaan uit 35 bladsye

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2

PHYSICAL SCIENCE HG (79)

Time: Three hours

Answer ALL the questions in SECTION A on the answer-sheet provided; answer any FOUR questions from SECTION B in your answer-book.

Consult the accompanying pamphlet with data where necessary.

SECTION A (COMPULSORY)

READ THE FOLLOWING INSTRUCTIONS CAREFULLY BEFORE ANSWERING THIS SECTION.

1. Use the printed answer-sheet enclosed with your question paper to answer this section.
 2. Write your EXAMINATION NUMBER in the space indicated.
 3. Use a PENCIL only on your answer-sheet.
 4. In the case of a wrong answer, erase the pencil mark completely.
 5. Do not make any other marks on your answer-sheet. Any calculations or writing that are necessary in the answering of the multiple choice questions 1 to 20, should be done in the answer-book and must be clearly deleted with a diagonal line across the page.
 6. The calculations for questions 21 to 28 should be done on pages 2 and 3 of the answer-sheet.
 7. PLACE THE COMPLETED ANSWER-SHEET INSIDE YOUR ANSWER-BOOK.
- A. Five possible answers, indicated by (a), (b), (c), (d) and (e), are supplied with each question. Choose only that answer which in your opinion is the correct or best answer and fill in the appropriate block on your answer-sheet.

Example

QUESTION: The symbol for hydrogen is

(a) S (b) W (c) H (d) N (e) P

ANSWER :

(a)
 (b)
 (c)
 (d)
 (e)

(Use a PENCIL only for filling in the blocks.
Each question has only one correct answer. If more than one block is filled in no marks will be given for that answer.)

PLEASE TURN OVER TO PAGE 4

1. A person walks 5 km North-east and then 5 km South-east. His displacement is

(a) 10 km
 (b) 7,07 km
 (c) 10 km East
 (d) 7,07 km East
 (e) 0 km.

(4)

2. An object with a mass of 5 kg is projected vertically upwards. The force necessary to take this object away from the earth's surface with a uniform acceleration of 3 m.s^{-2} is

(a) 49 N
 (b) 64 N
 (c) 15 N
 (d) 60 N
 (e) 150 N.

(4)

3. The accompanying sketch shows three point charges which are placed so that they form an equilateral triangle. The nature and magnitude of each charge is indicated. The arrow representing the resultant force on the $2 \mu\text{C}$ -charge is

$+2 \mu\text{C}$

(a) \rightarrow
 (b) \downarrow
 (c) \uparrow
 (d) \searrow
 (e) \leftarrow

$-3 \mu\text{C}$

$+3 \mu\text{C}$

(4)

4. A motor-car with a mass of 1000 kg is accelerated at a constant acceleration of 4 m.s^{-2} over a distance of 100 m. The amount of work done to accelerate the motor-car is

(a) $4 \times 10^5 \text{ J}$
 (b) $4 \times 10^2 \text{ J}$
 (c) $2,5 \times 10^4 \text{ J}$
 (d) $4 \times 10^1 \text{ J}$
 (e) 0 J.

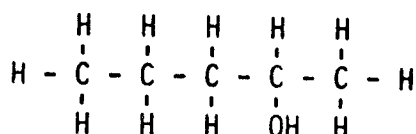
(4)

5. A transformer is connected to an alternating current source generating a current of 10 A. The transformer yields a maximum current of 0,5 A. If the potential difference across the primary coil is 220 V, the potential difference across the secondary coil will be
- (a) 1100 V
 - (b) 4400 V
 - (c) 440 V
 - (d) 44 V
 - (e) 11 V.
- (4)
6. An electron moves at a speed of $3 \times 10^5 \text{ m.s}^{-1}$. The kinetic energy of the electron is
- (a) $8,19 \times 10^{-20} \text{ J}$
 - (b) $1,365 \times 10^{-25} \text{ J}$
 - (c) $4,095 \times 10^{-20} \text{ J}$
 - (d) $1,01 \times 10^{-41} \text{ J}$
 - (e) $4,095 \times 10^{-22} \text{ J}$.
- (4)
7. Photo-electrons are emitted from zinc by the action of monochromatic radiation in the far ultra-violet region of the spectrum. A slight change in the number of electrons emitted per second will occur when there is a slight change in
- (a) the mass of the photon
 - (b) the value of Planck's constant
 - (c) the intensity of the incident light
 - (d) the frequency of the incident light
 - (e) the wavelength of the incident light.
- (4)
8. A trolley with a mass of 1 kg moves with a velocity of $0,5 \text{ m.s}^{-1}$. An object with a mass of 4 kg is dropped onto the trolley from above. The new velocity in m.s^{-1} of the trolley is
- (a) 8,0
 - (b) 1,25
 - (c) 0,9
 - (d) 0,1
 - (e) 0,2.
- (4)

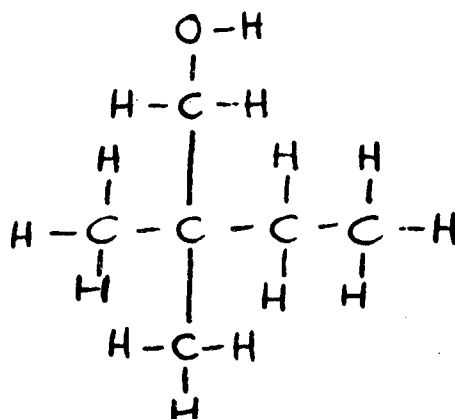
9. Two waves with the same frequency, and with amplitudes of 10 and 15 units respectively, are completely out of phase and approach a point P from opposite sides. The phenomenon which is observed and the amplitude at P are respectively
- destructive interference; 5 units
 - destructive interference; 25 units
 - constructive interference; 25 units
 - diffraction; 5 units
 - constructive interference; 5 units.
- (4)
10. Without pedalling, a boy rides a bicycle down a hill. The total mass of the boy and the bicycle is 50 kg. The hill is 60 m high. If 1 000 J work is done against friction, the total kinetic energy at the bottom of the hill is
- $2,94 \times 10^5$ J
 - $3,94 \times 10^4$ J
 - $2,94 \times 10^3$ J
 - $1,94 \times 10^3$ J
 - $2,84 \times 10^4$ J.
- (4)
11. An atom containing 7 neutrons is
- | | |
|-------------------------|-----------------------------|
| (a) ${}^{15}_7\text{N}$ | (b) ${}^{13}_6\text{C}$ |
| (c) ${}^7_3\text{Li}$ | (d) ${}^{28}_{14}\text{Si}$ |
| (e) ${}^5_2\text{He}$. | |
- (4)
12. An example of an atom used to illustrate Hund's Rule could be
- $1s^2 2s^2$
 - $1s^2 2s^2 2p^1$
 - $1s^2 2s^2 2p^2$
 - $1s^2 2s^2 2p^5$
 - $1s^2 2s^2 2p^6$.
- (4)
13. The total number of orbitals present in the third energy level of zinc is
- (a) 9 (b) 5 (c) 3 (d) 4 (e) 15. (4)

14. The shape of the water molecule can be understood by accepting
- that it is an ionic bond
 - hybridisation and lone pair repulsion
 - the formation of a dative covalent bond
 - the Bohr model of the atom
 - the orbital model of the atom.
- (4)
15. If AB and CB are both ionic compounds, and A and C are both in Group I, then the compound AD (where D is in the same group as B) will be ionic if
- A is above C in the group
 - A is below C in the group
 - B is above D in the group
 - B is below D in the group
 - B and D are not in Group VII.
- (4)
16. One of the differences between the structures of diamond and graphite is that graphite
- forms from sp^3 hybridisation
 - does not undergo hybridisation
 - is a form of sigma bonding
 - is tetrahedral
 - has an unhybridised p-orbital.
- (4)
17. The symbolic representation $Pt, H_2/H^+$ refers to the
- standard electrode potential
 - standard cell
 - redox potential
 - cell emf
 - standard electrode.
- (4)
18. In which of the following reactions does the oxidation number of sulphur decrease by 4?
- $S + O_2 \longrightarrow SO_2$
 - $2 MnO_4^- + 5 H_2S \longrightarrow 2 Mn^{2+} + 5 S + 8 H_2O$
 - $2 SO_2 + O_2 \longrightarrow 2 SO_3$
 - $2 HNO_3 + 3 H_2S \longrightarrow 2 NO + 3 S + 4 H_2O$
 - $2 H_2S + SO_2 \longrightarrow 2 H_2O + 3 S.$
- (4)

19. The two substances

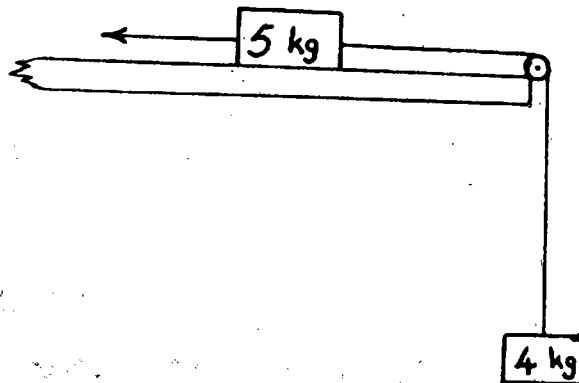


and



- (a) are isomers
 (b) are allotropes
 (c) come from a homologous series
 (d) are isotopes
 (e) bear no relationship. (4)
20. The difference in structure between an alkene and an alkyne is
- (a) related to the length of the carbon chain
 (b) caused by different types of hybridisation in carbon
 (c) caused by different isotopes of carbon
 (d) that an alkene is unsaturated
 (e) that an alkyne is unsaturated. (4)
- B. Do the calculations for each of the questions 21 to 28 on pages 2 and 3 of your answer-sheet. Where applicable the appropriate formula should be written down with your calculation.
21. An electric current flows in a conductor from a point where the potential is 100 V to a point where the potential is 10 V. How much work is done when a total charge of 0,5 C is moved between the two points in the circuit? (5)
22. Starting from rest an object with a mass of 2 kg falls freely. Calculate the kinetic energy gained by the object after it has fallen freely for 5 s. (5)
23. An electric motor works at a rate of 1,8 kW. Calculate the amount of work done by the motor in one minute. (5)

24. An object with a mass of 5 kg is supported on a horizontal frictionless surface and it is connected with string passing over a frictionless pulley to a hanging object with a mass of 4 kg. Calculate the force T necessary to give the object with a mass of 5 kg an acceleration of 4 m.s^{-2} to the left. ($g = 10 \text{ m.s}^{-2}$)



- (5)
25. How many moles of chlorine combine with 7 g hydrogen to form hydrogen chloride? (5)
26. Calculate the volume of a gas at STP if it occupied 58 cm^3 at a pressure of 40 kPa and at 17°C . (5)
27. An analysis of the reaction
- $$2 \text{SO}_2 (\text{g}) + \text{O}_2 (\text{g}) \rightleftharpoons 2 \text{SO}_3 (\text{g})$$
- in a 500 cm^3 container revealed the following quantities:
- SO_2 : 1,0 mol
- O_2 : 1,5 mol
- SO_3 : 2,5 mol
- Calculate the equilibrium constant for the reaction. (5)
28. Calculate the concentration of a solution of sulphuric acid that contains 29,4 g in a solution of 250 cm^3 . (5)

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- (i) What is the value of the acceleration represented by the portion AB of the graph?
- (ii) What does the portion CD of the graph indicate about the velocity of the object?
- (iii) What is the value of the acceleration represented by the portion DE of the graph?
- (iv) Calculate the distance covered by the object during the first 6 seconds.

(18)

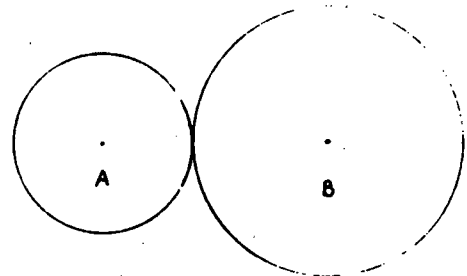
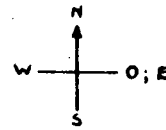
- (b) An aeroplane flies at a velocity of 100 m.s^{-1} horizontally over the sea at a height of 4410 m. An object with a mass of 50 kg is dropped out of the plane the moment it crosses a beacon B in the sea. Ignore the friction offered by the air. Calculate

- (i) the time the object takes to hit the water after it was dropped.
- (ii) how far from B the object will hit the water?

(10)

- (c) (i) Formulate Newton's Law of Universal Gravitation.

- (ii) Two spheres, A and B, of uniform density, touch each other. A has a mass of 30 kg and a *diameter* of 200 mm while B has a mass of 40 kg and a *diameter* of 300 mm.



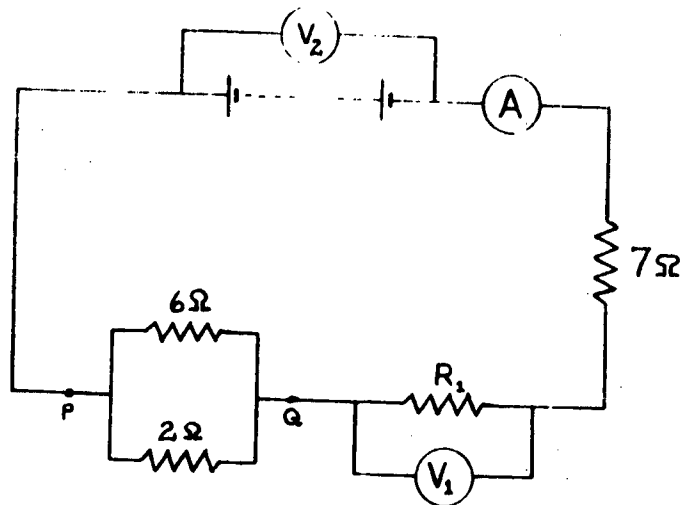
The force of gravitation between them can be determined with the aid of the equation

$$F = G \frac{m_1 \cdot m_2}{d^2}$$

- (1) What value of d must be used in this case?
- (2) $G = 6,7 \times 10^{-11} \text{ N.m}^2.\text{kg}^{-2}$. What will the value and unit of G be, if d is expressed in millimetre while F is still calculated in newton?
- (3) How is the value of F influenced if A is displaced 200 mm due West and B is displaced 300 mm due East?

(14)

(d)



The circuit diagram above represents a circuit consisting of a battery with negligible resistance connected in series with an ammeter A, which shows a reading of 3 A, a 7Ω resistor, a resistor R_1 and a set of two parallel resistors of 6Ω and 2Ω respectively. A voltmeter V_1 connected in parallel with resistor R_1 registers 1,5 V. A voltmeter V_2 is connected across the terminals of the battery.

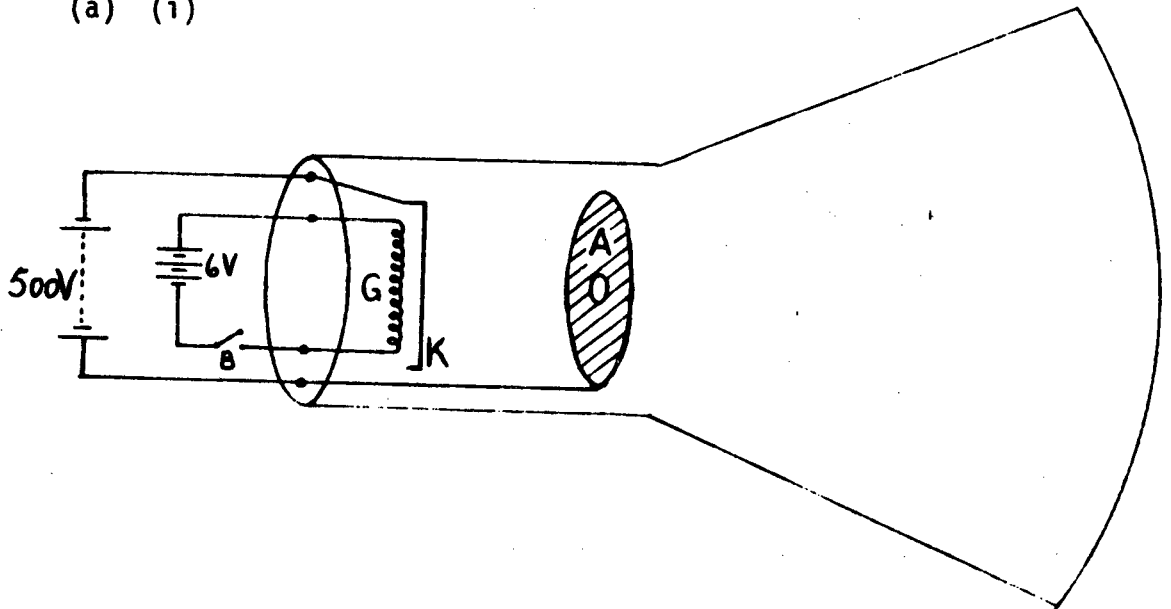
- (i) Calculate the effective resistance of the two parallel resistors.
- (ii) Calculate the resistance of resistor R_1 .
- (iii) Calculate the total resistance of the circuit.
- (iv) What will the reading on V_2 be?
- (v) Calculate the potential difference between the points P and Q.
- (vi) Calculate the current through the 6Ω resistor.
- (vii) The 6Ω and 2Ω resistors are connected in series instead of parallel. State, without doing any more calculations, what change there will be in the reading on the ammeter. Give a full explanation for your answer.

(28)

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(CATHODE RAY TUBE; MILLIKAN; WAVES)

3. (a) (i)



The sketch shows a simple cathode ray tube. A potential difference of 500 V is applied between the anode A and cathode K. The filament G is connected in series with a 6 V source and a switch B. Explain briefly the operation of the cathode ray tube when switch B is closed.

(ii)

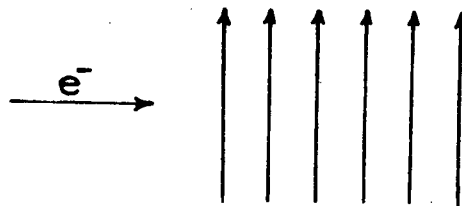


Figure A

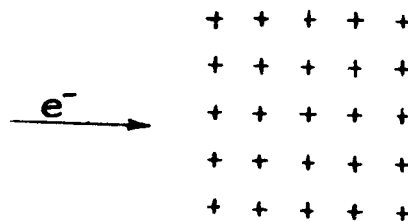


Figure B

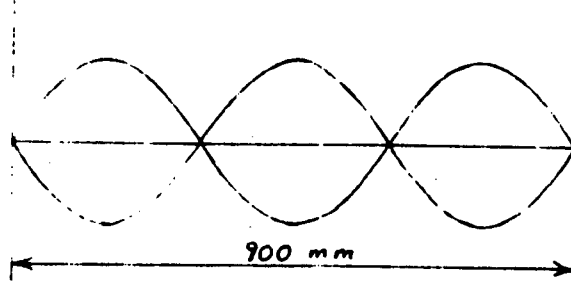
Show in each case by means of a sketch the path followed by a beam of electrons e^- that enter

- (1) a uniform electric field normal (perpendicular) to the direction of the field as shown in figure A and

- (2) a uniform magnetic field normal to the direction of the field as shown in figure B. (15)
- (b) In the oil drop experiment of Millikan a potential difference of 1000 V is applied across the two large parallel metal plates of a capacitor. The distance between the plates is 10 mm. An oil drop with a mass of $6,4 \times 10^{-15}$ kg is balanced between the two horizontal plates. If $g = 10 \text{ m.s}^{-2}$ calculate
- (i) the electric field strength between the plates;
 - (ii) the charge on the drop;
 - (iii) the number of electronic charges on the drop. (16)
- (c) (i) How is the initial charge on the oil drop in the experiment of Millikan obtained?
(ii) *Explain* how the charge on an observed oil drop can be changed. (6)
- (d) A lamp with a long straight glowing filament is placed behind a blue glass transmitting monochromatic blue light only. The filament is now viewed through
- (1) a narrow single slit;
 - (2) two narrow slits close to each other.
- (i) Describe the light patterns observed in each case clearly showing the differences.
 - (ii) Which part of the light pattern observed with the aid of the double slit is the result of
 - (1) constructive interference
 - (2) destructive interference?
 - (iii) If a red glass instead of the blue glass is placed in front of the light source, in what respects and why is there a difference in the pattern observed with the aid of the single slit? (15)
- (e) The light of one of the lines in the line spectrum of hydrogen has a frequency of $7,0 \times 10^{14}$ Hz. Calculate
- (i) the wavelength and
 - (ii) the energy of a photon of this light. (10)

(f) The accompanying sketch represents a standing wave.

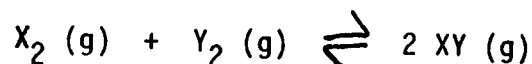
- (i) What is the wavelength of the wave?
- (ii) The frequency of the wave is 60 Hz. Calculate the velocity of the wave in m.s^{-1} .



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(ATOMIC STRUCTURE; SOLUTIONS; EQUILIBRIUM)

4. (a) A sample of potassium is analysed and found to have the atomic structure ${}_{19}^{39}\text{K}$.
- (i) Use the arrow-in-circle notation to show its electron configuration.
- (ii) Write down the set of quantum numbers that describe the outermost electron in this atom. Should it be possible that any of the quantum numbers could have more than one value, this should be indicated.
- (iii) What is the shape of the orbital containing this outermost electron?
- (iv) State Pauli's Exclusion Principle.
- (v) What are *isotopes*? Write down the structure of an isotope of potassium. (8)
- (b) Some iodine crystals are added to a test-tube containing equal volumes of water and carbon tetrachloride.
- (i) State what you would observe.
- (ii) Briefly describe the process that occurs in each liquid layer when the crystals are added, showing clearly the forces involved. (17)
- (c) A hypothetical reaction is represented by the equation:



- (i) What is the meaning of the equilibrium sign used?
- (ii) Briefly state Le Chatelier's Principle.
- (iii) What effect will a rise in temperature have on this reaction?
- (iv) State, with reasons, the effect of an increase in pressure on the value of the equilibrium constant. (22)

(BONDING; REACTION RATES; ACIDS; OXIDATION-REDUCTION)

5. (a) Hydrogen chloride is a typical example of a covalent molecule.

(i) Write down the Lewis structure for this molecule.

(ii) Suggest *two* limitations of a Lewis structure.

(iii) Describe carefully how this molecule forms from the two atoms that approach each other, and draw the resultant shape of the orbitals.

(iv) Briefly state the meaning of the following:

(aa) sigma-bond

(bb) pi-bond

(cc) dative covalent bond.

(v) What further information can you provide about the nature of the covalent bond in this molecule? Mention the basis on which you make this statement.

(37)

(b) The rate at which hydrogen chloride reacts with water will be influenced by temperature.

(i) What two properties of the molecules will influence the effectiveness of collisions between them?

(ii) Explain how a rise in temperature increases the reaction rate.

(10)

(c) Water is an important molecule in reactions involving acids, in that it is amphiprotic.

(i) What is the meaning of *amphiprotic*?

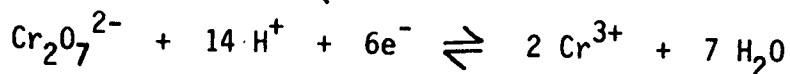
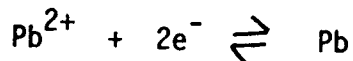
(ii) Give two clearly labelled reactions that indicate the amphiprotic behaviour of water.

(iii) State the value of the ionisation constant of water at 298 K.

(iv) What use has been made of this value given in your answer to (iii)?

(13)

(d) The half-reactions, taken from the table of standard redox potentials for lead and the dichromate ion are



(i) Balance the equation for the reaction, showing your working.

(ii) Name the reducing agent.

(10)

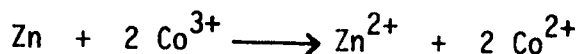
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(ATOMIC STRUCTURE; GASES; ELECTROCHEMICAL CELLS; ORGANIC CHEMISTRY)

6. (a) The Bohr model of the atom assumed the existence of energy levels as a basic concept.
- (i) What was the main shortcoming of this model?
 - (ii) An improvement to this model was the *orbital* approach. What is an orbital?
 - (iii) What are the limitations in presenting an orbital in a drawing? (12)

- (b) A study of gases is based on the assumption that most gases are *ideal* gases.
- (i) What is meant by saying a gas behaves as an *ideal gas*?
 - (ii) State the two conditions which cause *non-ideal* behaviour in gases, and explain briefly why each of these conditions affects the gas.
 - (iii) Write down the general ideal gas law equation.
 - (iv) For each symbol in the equation given in (iii) write down the meaning of the symbol and the unit in which it is measured. (25)

- (c) The nett reaction for an electrochemical cell is



- (i) Write down the symbolic representation of this cell.
- (ii) Which way do electrons flow in the external circuit of this cell?
- (iii) The nett reaction for another cell is



This reaction causes a small torch bulb to be dimly lit. State, with reasons, what value you think the standard redox potential of $\text{Co}^{2+}/\text{Co}^{3+}$ is.

- (iv) If the reaction in (iii) causes a small torch bulb to be dimly lit, what can you say about the reaction given at the start of this question? (19)

- (d) An organic series consists of acids containing the carboxyl group.
- (i) Considering the structure of this group, why do you think the group is called *carboxyl*?
 - (ii) Draw the structural formula of the acid with two carbon atoms.
 - (iii) Explain why this substance you have drawn in (ii) is classified as an acid.
 - (iv) Name the substance with which the acid in (ii) must react to form methyl ethanoate.

(14)
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B. PHYSICAL SCIENCE (STANDARD GRADE)

NATUUR- EN SKEIKUNDE SG

80

PHYSICAL SCIENCE SG

1976

DEPARTEMENT VAN ONDERWYS
KAAP DIE GOEIE HOOP

DEPARTMENT OF EDUCATION
CAPE OF GOOD HOPE

SENIOR SERTIFIKAAT-EKSAMEN
SENIOR CERTIFICATE EXAMINATION

Skryf op die voor-buiteblad van u antwoordeboek, teenoor die woord "Vak" -

NATUUR- EN SKEIKUNDE STANDAARD GRAAD

Write on the front cover of your answer-book, after the word "Subject" -

PHYSICAL SCIENCE STANDARD GRADE

Hierdie vraestel bestaan uit 27 bladsye
This examination paper consists of 27 pages

BLAAI OM ASSEBLIEF / PLEASE TURN OVER

PHYSICAL SCIENCE STANDARD GRADE

Three hours

Answer ALL the questions in SECTION A on the answer-sheet provided; answer any FOUR questions from SECTION B in your answer-book.

Consult the accompanying pamphlet with data where necessary.

SECTION A (COMPULSORY)

READ THE FOLLOWING INSTRUCTIONS CAREFULLY BEFORE ANSWERING THIS SECTION.

1. Use the printed answer-sheet enclosed with your question paper to answer this section.
 2. Write your EXAMINATION NUMBER in the space indicated.
 3. Use a PENCIL only on your answer-sheet.
 4. In the case of a wrong answer, erase the pencil mark completely.
 5. Do not make any other marks on your answer-sheet. Any calculations or writing that are necessary in the answering of questions 1 to 30, should be done in the answer-book and must be clearly deleted with a diagonal line across the page.
 6. The calculations for questions 31 to 36 should be done on pages 2 and 3 of the answer-sheet.
 7. PLACE THE COMPLETED ANSWER-SHEET INSIDE YOUR ANSWER-BOOK.
- A. Four possible answers, indicated by (a), (b), (c) and (d), are supplied with each question. Choose only that answer which in your opinion is the correct or best answer and fill in the appropriate block on your answer-sheet.

Example

QUESTION: The symbol for hydrogen is

(a) S (b) W (c) H (d) N

ANSWER :
(a) (b) (c) (d)

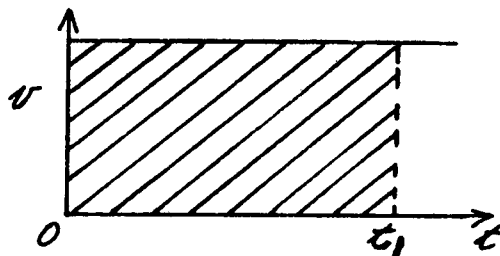
(Use a PENCIL only for filling in the blocks. Each question has only one correct answer. If more than one block is filled in no marks will be given for that answer.)

PHYSICAL SCIENCE STANDARD GRADE

1. The phenomenon which causes the formation of a spectrum when white light passes through a prism is called
 - (a) diffraction
 - (b) interference
 - (c) dispersion
 - (d) reflection.(3)
2. A metallic object which is not insulated, cannot be charged electrostatically because
 - (a) the charge spreads over the surface
 - (b) it has no free electrons
 - (c) no suitable rubbing material can be found for metals
 - (d) the charge is lost to surrounding bodies.(3)
3. Moving electrons are *not* deflected by
 - (a) magnetic fields
 - (b) nearby protons
 - (c) nearby neutrons
 - (d) electric fields.(3)
4. Blue light is diffracted less than red light by a narrow slit, because
 - (a) the speed of blue light is greater than that of red light
 - (b) blue light has a shorter wave-length than red light
 - (c) red light has a shorter wave-length than blue light
 - (d) for the same intensity of irradiation, blue light appears brighter than red light.(3)
5. Thermionic emission is
 - (a) the radiation of heat by a hot wire
 - (b) the extraction of electrons from a metal surface by a strong electric field
 - (c) the release of electrons from a metal surface by light rays
 - (d) the release of electrons from a metal surface by heating.(3)
6. A quantum of electromagnetic radiation is called
 - (a) a photon
 - (b) a proton
 - (c) an electron
 - (d) a neutron.(3)

PHYSICAL SCIENCE STANDARD GRADE

7. The product of the mass of a body and its velocity is called
- kinetic energy
 - potential energy
 - power
 - momentum. (3)
8. When a force acts on a body which is free to move, work is done only if
- the force and the motion are perpendicular to each other
 - the force has a component in the direction of the motion
 - the force is greater than the weight of the body
 - there is no friction. (3)
9. The velocity/time graph for a vehicle is given in the diagram below



- The shaded area in the diagram represents
- the acceleration at time t_1
 - the velocity after time t_1
 - the distance covered in time t_1
 - the speed after time t_1 . (3)
10. An electric current flows in the same direction in each of two parallel wires. If the current through the wires is doubled, the force between them will be
- four times the original force
 - the same as the original force
 - one half of the original force
 - one quarter of the original force. (3)

PHYSICAL SCIENCE STANDARD GRADE

11. One mole of sodium contains the same number of atoms as
- (a) 16 g zinc
 - (b) 31 g copper
 - (c) 12 g carbon
 - (d) 6 g carbon.
- (3)
12. Potassium reacts more vigorously with water than sodium because potassium has
- (a) a lower ionisation energy
 - (b) a higher electronegativity
 - (c) a greater nuclear charge
 - (d) a larger atomic radius.
- (3)
13. Elements in the same period have
- (a) the same valence
 - (b) similar chemical properties
 - (c) similar electron configurations
 - (d) different electron configurations.
- (3)
14. The forces that hold sodium ions and chloride ions together in the crystal can be described as
- (a) hydrogen bonds
 - (b) metallic bonds
 - (c) Van der Waals forces
 - (d) Coulomb forces.
- (3)
15. If the compound XY represents a higher energy state than the individual atoms X and Y, we can predict that
- (a) combination will take place readily
 - (b) bonding is unlikely to occur
 - (c) an ionic bond is probable
 - (d) a covalent bond is probable.
- (3)
16. Deviations from the ideal gas laws are likely to occur
- (a) because gases exert partial pressures in a mixture
 - (b) because Van der Waals forces are rare in gases
 - (c) at low temperature
 - (d) at low pressure.
- (3)

PHYSICAL SCIENCE STANDARD GRADE

- C. Do the calculations for each of the questions 31 to 36 on pages 2 and 3 of your answer-sheet. Where applicable, write down the appropriate formula for your calculation.
31. A ball, thrown vertically upwards from ground level, reaches the ground after 12 s. If $g = 10 \text{ m.s}^{-2}$, calculate the velocity with which the ball was thrown up. (4)
32. Calculate the gravitational force of attraction between two spherical bodies of mass 1 kg each and with their centres 100 mm apart. (6)
33. A current of 2 A flows in a resistor with a resistance of 5 ohm for half a minute. Calculate the quantity of energy which has been transferred in the resistor. (5)
34. Calculate how many moles of nitrogen (at STP) are needed to form 224 dm^3 ammonia in the reaction
$$3 \text{ H}_2 (\text{g}) + \text{N}_2 (\text{g}) \longrightarrow 2 \text{ NH}_3 (\text{g})$$
 (5)
35. What pressure (in kPa) must be applied to 60 cm^3 of nitrogen at STP to compress it to 40 cm^3 while the temperature remains constant? (5)
36. Calculate the concentration of a solution of sodium hydroxide containing 10 g (NaOH) in 1 dm^3 . (5)

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PHYSICAL SCIENCE STANDARD GRADESECTION B

Answer any FOUR questions. (Use $g = 10 \text{ m.s}^{-2}$ where necessary)

(MOMENTUM; EQUATIONS OF MOTION; WORK; ENERGY)

1. (a) A cannon fires a 15 kg shot horizontally at a velocity of 600 m.s^{-1} in a westerly direction. The mass of the cannon is 1 200 kg. Ignore the friction offered by the ground.
- (i) Calculate (1) the magnitude and direction of the momentum of the cannon ball at the instant it leaves the barrel of the cannon
- (2) the magnitude and direction of the velocity with which the cannon recoils.
- (ii) State and formulate in words the principle which is applicable here. (22)
- (b) In the kinematic equations $s = ut + \frac{1}{2}at^2$ and $v^2 = u^2 + 2as$, five different symbols, s, u, v, a and t are used. For each symbol
- (i) explain its meaning
- (ii) give the SI unit in which it is expressed
- (iii) state whether it is a vector quantity or a scalar quantity. (15)
- (c) A crate, mass 10 kg, is pulled 5 m along a level floor by a constant horizontal force of 20 N. The crate is then lifted onto a platform 3 m above floor level. If $g = 10 \text{ m.s}^{-2}$, calculate
- (i) the total amount of work done
- (ii) the amount of energy which is transformed into potential energy. (13)

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PHYSICAL SCIENCE STANDARD GRADE

(RECTANGULAR COMPONENTS OF FORCES; CURRENT ELECTRICITY; OHM'S LAW)

2. (a) Two forces, A and B, act on a point O:

$$A = 300 \text{ N in a direction } N 30^\circ E$$

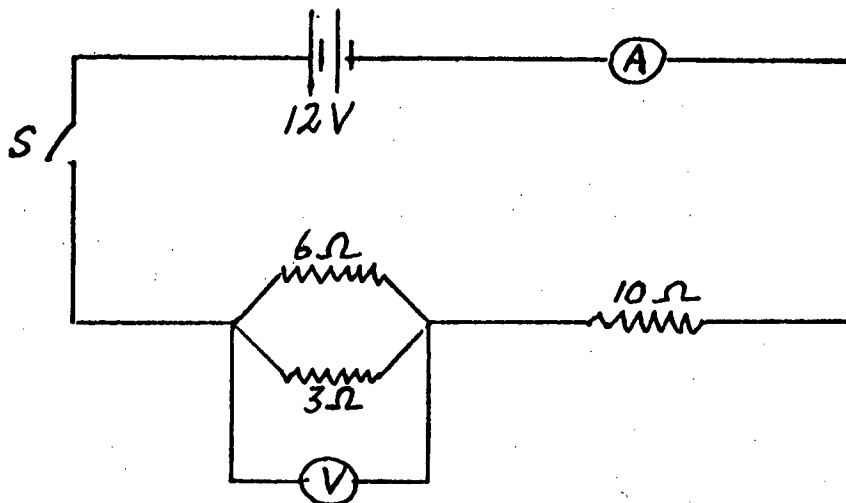
$$B = 200 \text{ N in a direction } E 30^\circ N.$$

Determine by accurate drawing, using the scale
10 mm = 50 N, or by calculation,

(i) the magnitude and direction of OR, the resultant force

(ii) the components ON and OE of force A in the northerly and easterly directions respectively. (28)

(b) A diagram of an electric circuit is given below:



- (i) Calculate
- (1) the equivalent resistance of the parallel resistors
 - (2) the total resistance of the circuit
 - (3) the readings on the ammeter A and voltmeter V respectively when switch S is closed
 - (4) the power supplied by the battery.

(ii) State *Ohm's Law* in words.

(22)

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PHYSICAL SCIENCE STANDARD GRADE

(STATIC ELECTRICITY; ELECTRIC FIELD STRENGTH; WAVES)

3. (a) Two point charges of $+5 \mu\text{C}$ and $+10 \mu\text{C}$ respectively are 3 m apart in a vacuum.
- (i) Calculate the electrostatic force between them.
- (ii) Is this an attractive or a repelling force? Submit a reason for your answer. (12)
- (b) The potential difference between two large horizontal parallel plates is 500 V. The plates are 25 mm apart.
- (i) Sketch the electric field between the plates.
- (ii) Calculate (1) the strength of the electric field
- (2) the force that would be experienced by a charge of $+1.5 \times 10^{-18} \text{ C}$ if it were placed in this field
- (3) the work done when this charge is moved slowly through a distance of 10 mm in a direction opposite to that of the field. (25)
- (c) What experimental evidence can you submit to prove that electrons reveal (i) a particle nature
- (ii) a wave nature. (4)
- (d) The frequency of certain light waves is $5 \times 10^{14} \text{ Hz}$.
- Calculate (i) the period of the waves
- (ii) the wave-length of the light. (9)

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(ATOMIC STRUCTURE; BONDING; ELECTROCHEMISTRY; OXIDATION-REDUCTION)

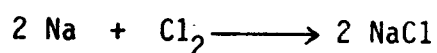
4. (a) When a hydrogen discharge tube is connected to a source of high voltage and viewed through a diffraction grating a bright line spectrum will be observed.
- (i) What four colours will be seen?
- (ii) The Bohr model of the atom tried to explain the origin of these lines. State two aspects of this model.
- (iii) What was the main shortcoming of this model? (16)

PHYSICAL SCIENCE STANDARD GRADE

- (b) Molecules tend to exert forces of attraction on each other.
- (i) What are these forces called?
 - (ii) In what three respects do these forces differ from covalent bonds?
 - (iii) Mention the type of bond which causes water to have such a high boiling point. (10)

- (c) Powdered zinc is added to a solution of copper(II) sulphate and stirred until the reaction is complete.
- (i) What will you observe?
 - (ii) How can this reaction be used to produce a flow of electrons?
 - (iii) Give the name of the arrangement described in (ii).
 - (iv) Write down the nett equation for the above reaction. (16)

- (d) The reaction



is a redox reaction.

- (i) What is oxidation?
 - (ii) Name the oxidising agent in this reaction.
 - (iii) Explain your answer in (ii) by referring to the change in oxidation number. (8)
- /50/

(BONDING; GASES; SOLUTIONS; ACIDS)

5. (a) Hydrogen chloride is a covalent molecule.
- (i) Which atomic orbitals overlap to form the covalent bond in this molecule?
 - (ii) Give the Lewis structure for this molecule.
 - (iii) Is the molecule polar or non-polar? Give the reason for your answer.
 - (iv) Briefly describe the distribution of the electrons involved in the bond. (14)

PHYSICAL SCIENCE STANDARD GRADE

- (b) An experiment has been performed to investigate the relationship between the pressure of a gas at the ice-point (freezing point) of water and its pressure at the steam-point (boiling point) of water (volume constant)
- (i) Write down an equation to show this relationship.
 - (ii) How is the temperature scale defined from this experiment?
 - (iii) Name the temperature scale used in the SI units.
 - (iv) State the ideal gas law.
 - (v) Write down the approximate value of room temperature this morning, using the scale mentioned in (iii) (14)
- (c) Ionic compounds tend to dissolve in water.
- (i) What type of solvent is water?
 - (ii) Give the name of the process that takes place in the reaction $\text{NaCl} \longrightarrow \text{Na}^+ + \text{Cl}^-$
 - (iii) What happens to the ions in water?
 - (iv) Write down the symbol for an ion in solution. (9)
- (d) A sodium hydroxide solution is added from a burette to a solution of hydrochloric acid, to which bromothymol blue has been added.
- (i) Name this type of experimental procedure.
 - (ii) What is the name of this type of chemical reaction?
 - (iii) State the colour of the bromothymol blue before the burette tap is opened.
 - (iv) What is the function of the bromothymol blue? What is this type of substance called?
 - (v) What is the approximate pH of the solution in the burette? (13)

/50/

PHYSICAL SCIENCE STANDARD GRADE

(ATOMIC STRUCTURE; SOLIDS; REACTION RATES; EQUILIBRIUM;
ORGANIC CHEMISTRY)

6. (a) An atom has an electron configuration $1s^2 2s^2 2p^6 3s^2$
- (i) Name the element.
 - (ii) Write down the symbol for the ion it forms, and its electron configuration.
 - (iii) How many unpaired electrons are there in the atom?
 - (iv) If the atom contained 13 neutrons, what would its mass number be? (10)
- (b) Solids are often characterised by a particular arrangement of their particles.
- (i) How do the forces binding the particles compare with those in the other phases?
 - (ii) What is the name given to a collection of solid particles with plane surfaces and having characteristic angles?
 - (iii) In one sentence, state what a unit cell is.
 - (iv) What shape does diamond have? (9)
- (c) Different chemical reactions occur at different rates, and this will be influenced by the nature of the reacting substances. Name four other factors that affect the rate of a reaction. (8)
- (d) Hydrogen combines with iodine in an exothermic reaction according to the equation $H_2 (g) + I_2 (g) \rightleftharpoons 2 HI (g)$
- (i) What is an *exothermic* reaction?
 - (ii) State what you understand by 'dynamic equilibrium'
 - (iii) How will the concentration of hydrogen iodide be affected by:
 - (1) an increase in pressure
 - (2) an increase in temperature? (11)

PHYSICAL SCIENCE STANDARD GRADE

- (e) Organic chemistry is a separate branch of chemistry having many carbon compounds.
- (i) On what property of the carbon atom is the existence of the multiplicity of these compounds based?
 - (ii) Write down the general formula of the saturated hydrocarbons.
 - (iii) What is the general name of these saturated hydrocarbons?
 - (iv) State two uses of plastics.

(12)
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PHYSICAL SCIENCE SG

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NATUUR- EN SKEIKUNDE SG

1977

DEPARTMENT OF EDUCATION
CAPE OF GOOD HOPE
DEPARTEMENT VAN ONDERWYS
KAAP DIE GOEIE HOOP

SENIOR CERTIFICATE EXAMINATION
SENIOR SERTIFIKAAT-EKSAMEN

Write on the front cover of your answer-book, after the word "Subject" -

PHYSICAL SCIENCE STANDARD GRADE

Skryf op die voor-buiteblad van u antwoordeboek, teenoor die woord "Vak" -

NATUUR- EN SKEIKUNDE STANDAARD GRAAD

This examination paper consists of 27 pages
Hierdie vraestel bestaan uit 27 bladsye

PLEASE TURN OVER / BLAAI OM ASSEBLIEF

Time: Three hours

Answer ALL the questions in SECTION A on the answer-sheet provided; answer any FOUR questions from SECTION B in your answer-book.

Consult the accompanying pamphlet with data where necessary.

SECTION A (COMPULSORY)

READ THE FOLLOWING INSTRUCTIONS CAREFULLY BEFORE ANSWERING THIS SECTION.

1. Use the printed answer-sheet enclosed with your question paper to answer this section.
2. Write your EXAMINATION NUMBER in the space indicated.
3. Use a PENCIL only on your answer-sheet.
4. In the case of a wrong answer, erase the pencil mark completely.
5. Do not make any other marks on your answer-sheet. Any calculations or writing that are necessary in the answering of questions 1 to 30, should be done in the answer-book and must be clearly deleted with a diagonal line across the page.
6. The calculations for questions 31 to 36 should be done on pages 2 and 3 of the answer-sheet.
7. PLACE THE COMPLETED ANSWER-SHEET INSIDE YOUR ANSWER-BOOK.
- A. Four possible answers, indicated by (a), (b), (c) and (d), are supplied with each question. Choose only that answer which in your opinion is the correct or best answer and fill in the appropriate block on your answer-sheet.

Example

QUESTION: The symbol for hydrogen is

(a) S (b) W (c) H (d) N

ANSWER:

| | | | |
|--------------------------|--------------------------|-------------------------------------|--------------------------|
| <input type="checkbox"/> | <input type="checkbox"/> | <input checked="" type="checkbox"/> | <input type="checkbox"/> |
| (a) | (b) | (c) | (d) |

(Use a PENCIL only for filling in the blocks. Each question has only one correct answer. If more than one block is filled in no marks will be given for that answer.)

PLEASE TURN OVER TO PAGE 4

1. The weight in newton of a mass piece of 10 kg is approximately

- (a) 9,8
- (b) 1
- (c) 98
- (d) 32. (3)

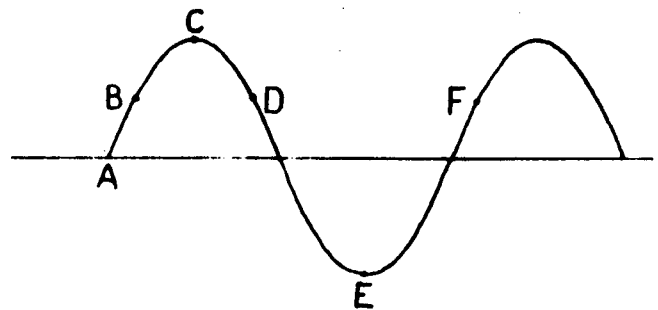
2. The repulsive force between two positive point charges is F . If each point charge is doubled, the force of repulsion will be

- (a) $0,5 F$
- (b) $0,25 F$
- (c) $4 F$
- (d) $2 F$. (3)

3. The minimum resultant of a 20 N force and a 5 N force is

- (a) 15 N
- (b) 100 N
- (c) 0 N
- (d) 25 N. (3)

4. The accompanying diagram shows the profile of a transverse wave. The points on the wave which are in phase are



- (a) B and D
- (b) A, B and C
- (c) C and E
- (d) B and F. (3)

5. An object moves from a position of rest at a uniform acceleration of 5 m.s^{-2} . The distance travelled in 10 s is

- (a) 500 m
- (b) 250 m
- (c) 100 m
- (d) 50 m. (3)

6. A direct current source maintains a potential difference of 6 V across the terminals of a lamp so that a steady current of 0,3 A flows through the lamp for 3 min. The resistance, in ohm, of the lamp is

- (a) 1,8
- (b) 18
- (c) 20
- (d) 10. (3)

7. The quantity of charge, in coulombs, passing through the lamp in question 6 is
- (a) 54
(b) 10
(c) 0,1
(d) 2. (3)
8. The electromagnetic waves with the lowest frequency are known as
- (a) infra-red rays
(b) radio waves
(c) ultra-violet rays
(d) X-rays. (3)
9. Which one of the following waves cannot be polarised?
- (a) sound waves
(b) infra-red waves
(c) X-rays
(d) ultra-violet waves. (3)
10. The current between the anode and cathode of a thermionic diode consists of
- (a) photons flowing from the anode to the cathode
(b) photons flowing from the cathode to the anode
(c) electrons flowing from the anode to the cathode
(d) electrons flowing from the cathode to the anode. (3)
11. The atom ${}^9_4\text{Be}$ contains
- (a) 9 electrons (b) 5 protons
(c) 9 neutrons (d) 4 protons. (3)
12. Two atoms having the structures ${}^{13}_7\text{N}$ and ${}^{14}_7\text{N}$ are called
- (a) isomers (b) polyprotic
(c) isotopes (d) allotropes. (3)
13. When the following process takes place
- $$\text{Na} \longrightarrow \text{Na}^+ + \text{e}^-$$
- the energy change is called
- (a) electron affinity
(b) ionisation energy
(c) electronegativity
(d) lattice energy. (3)

14. The change $I_2 (s) \longrightarrow I_2 (g)$ is known as
(a) fusion (b) sublimation
(c) vaporisation (d) condensation. (3)
15. An example of a macromolecular covalent solid is
(a) diamond
(b) sodium chloride
(c) ice
(d) iodine. (3)
16. If 10 cm^3 dilute hydrochloric acid is added to 10 cm^3 of a solution of sodium hydroxide of the same concentration, the final pH will be
(a) 0 (b) 13
(c) 7 (d) 1. (3)
17. The standard electrode is
(a) hydrogen (b) oxygen
(c) zinc (d) copper. (3)
18. The anode in the reaction
$$\text{Zn} + \text{Cu}^{2+} \longrightarrow \text{Zn}^{2+} + \text{Cu}$$
is
(a) Zn (b) Zn^{2+}
(c) Cu (d) Cu^{2+} . (3)
19. The strongest oxidising agent among the halogens is
(a) chlorine (b) bromine
(c) fluorine (d) iodine. (3)
20. The oxidation number of manganese in KMnO_4 is
(a) +1 (b) -2
(c) +2 (d) +7. (3)

- B. For each of the questions 21 to 30, write down in the block on your answer-sheet, the letter according to your selection of items from list B which is best associated with each item in list A. It is possible that any one of the items in list B may be used more than once.

List A

21. Helium nucleus
22. velocity
23. Unit of power
24. Thermionic emission
25. Polarisation
26. Couper structure
27. p-p overlapping
28. delocalised electrons
29. pyramidal molecule
30. coulomb forces

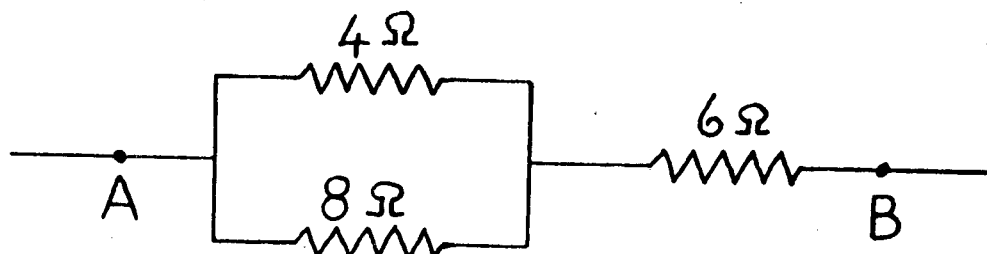
List B

- (a) scalar
- (b) watt
- (c) cathode-ray tube
- (d) alpha particle
- (e) vector
- (f) transverse waves
- (g) kilojoule
- (h) longitudinal waves
- (j) H:Cl
- (k) Cl₂
- (l) H₂
- (m) H - Br
- (n) NH₃
- (o) dipole
- (p) metallic bond
- (q) ionic bond.

(10)

- C. Do the calculations for each of the questions 31 to 36 on pages 2 and 3 of your answer-sheet. Where applicable, write down the appropriate formula for your calculation.

31.



- Calculate the total resistance between points A and B in the circuit. (5)
32. An object with a mass of 2 kg travels at a speed of 3 m.s^{-1} . It is accelerated in 0,5 s to a speed of 7 m.s^{-1} . Calculate the force necessary to accelerate the object. (5)
33. An object falls from rest a distance of 1800 mm in 0,6 s. Ignore air friction and calculate the value of g at this place. (5)
34. From the reaction
- $$\text{N}_2 + 3 \text{H}_2 \longrightarrow 2 \text{NH}_3$$
- calculate the number of moles of ammonia produced when 56 g nitrogen reacts with excess hydrogen. (5)
35. 118 cm^3 of a gas are collected at 22°C . What would the volume be if the temperature was raised to 77°C while the pressure remained constant? (5)
36. For the reaction
- $$\text{KOH} + \text{HNO}_3 \longrightarrow \text{KNO}_3 + \text{H}_2\text{O}$$
- calculate the volume of acid having concentration $0,2 \text{ mol.dm}^{-3}$ required to neutralise 60 cm^3 base of concentration $0,3 \text{ mol.dm}^{-3}$. (5)

SECTION B

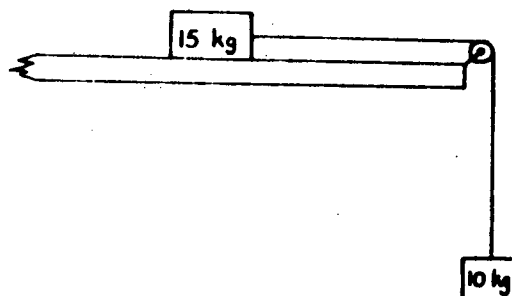
Answer any FOUR questions.

(VECTORS; EQUATIONS OF MOTION; MOMENTUM)

1. (a) Complete the following sentence by simply writing down the missing words next to the appropriate numbers:

A scalar quantity is a physical quantity which has only (i) while a vector quantity is characterised by both (ii) and (iii). (6)

- (b) An object with a mass of 15 kg is supported on a horizontal frictionless surface. An object with a mass of 10 kg is connected to the 15 kg object by means of string passing over a frictionless pulley as shown in the figure. If the weight of the 10 kg object which sets the system in motion is 100 N, calculate



- (i) the acceleration of the 10 kg object;
 (ii) the horizontal acceleration of the 15 kg object;
 (iii) the horizontal force acting on the 15 kg object. (16)

- (c) A boy with a mass of 40 kg runs due North at a velocity of 3 m.s^{-1} . He jumps on a stationary wagon that stands on a horizontal smooth surface.

The wagon, with the boy on it, now moves due North at a velocity of 2 m.s^{-1} . Calculate

- (i) the momentum of the boy before he jumps on the wagon;
 (ii) the mass of the wagon. (13)

- (d) A motor-car travels at a constant speed of 20 m.s^{-1} on a straight road. At a certain moment it starts to accelerate uniformly at $0,4 \text{ m.s}^{-2}$. Calculate
- the speed of the motor-car 10 s after it started to accelerate;
 - the distance travelled during this time interval;
 - the kinetic energy of the motor car at the end of this time interval if the mass of the motor car is 1000 kg.

(15) /50/

(VECTORS; COMPONENTS OF A FORCE; CURRENT ELECTRICITY)

2. (a) Two unbalanced forces F_1 and F_2 act on a point mass P.

$F_1 = 400 \text{ N}$ in the direction 45° (or in the direction 45° E of N)

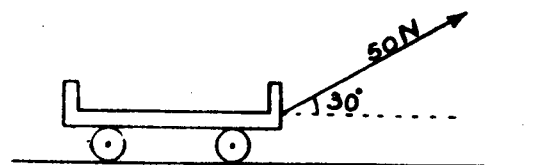
$F_2 = 300 \text{ N}$ in the direction 150° (or in the direction 60° S of E).

- Determine either by accurate drawing and measurement, using the scale $10 \text{ mm} = 50 \text{ N}$, or by calculation
 - the magnitude of the resultant force on P;
 - the direction in which the point mass will move.
- What is the magnitude and direction of a third force F_3 that should be applied to keep the point mass P in equilibrium?

(21)

- (b) The figure shows a trolley moving horizontally under the action of a force of 50 N, which is inclined at an angle of 30° to the horizontal.

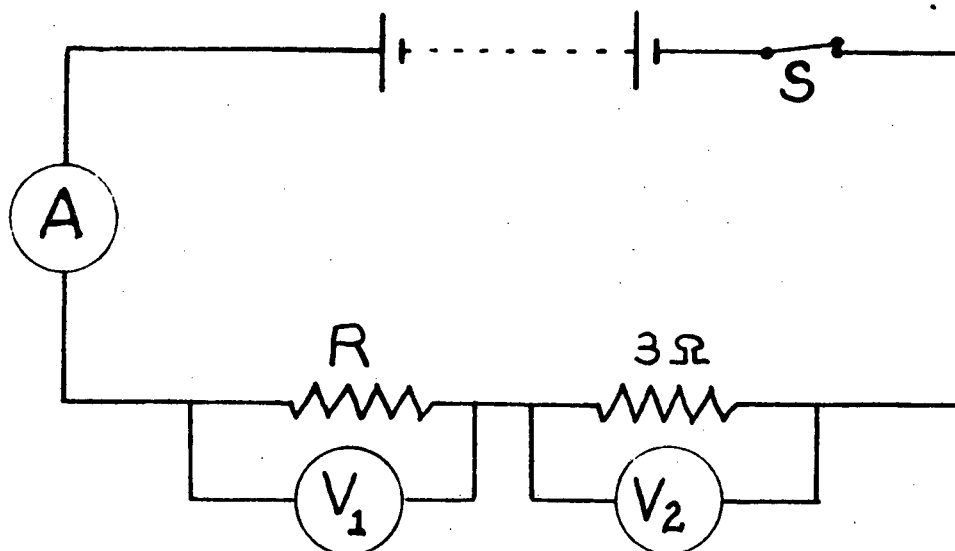
Determine either by accurate drawing and measurement using the scale $10 \text{ mm} = 5 \text{ N}$, or by calculation



- the horizontal component of the applied force which tends to move the trolley to the right;
- the vertical component of the applied force which tends to lift the trolley.

(11)

(c)

 V_1 registers 15 V V_2 registers 9 V

- (i) Describe briefly how the various electric components shown in the diagram, are connected.
- (ii) Calculate the current through the 3Ω resistor when switch S is closed.
- (iii) Give the reading on A when switch S is closed.
- (iv) What is the value of the current in R?
- (v) Calculate the resistance of resistor R.
- (vi) Calculate the total resistance of the two resistors.

(18)

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(WAVES; ELECTROSTATIC FORCES; TRANSFORMER)

3. (a) A monochromatic beam of light has a frequency of 7×10^{14} Hz. Calculate

- (i) the energy of a photon of this light;
- (ii) the wave-length of this light.

(10)

- (b) (i) Make a sketch of the electric field pattern around and between two identical negative point charges A and B separated by a distance s .
- (ii) Indicate a point C in the field where a proton will experience no force from the electric field.
- (iii) Indicate any point D in the field where an electron will experience a force. Use an arrow to indicate the force exerted on an electron at point D.

- (iv) The charge on A is $-8 \times 10^{-14} \text{C}$. Is there an excess of electrons or protons on A?
- (v) Calculate the excess of electrons or protons on A. (20)
- (c) (i) Name *three* properties of electromagnetic waves.
(ii) State briefly how electromagnetic radiation is generated. (8)
- (d) (i) Illustrate with the aid of a diagram what is meant by the diffraction of a wave.
(ii) Name two factors which influence the degree of diffraction. (8)
- (e) A transformer is used to convert 220 V a.c. to 5 V a.c.
- (i) What type of transformer is used?
(ii) What is the ratio of the number of turns in the primary coil to the number of turns in the secondary coil? (4)

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(ATOMIC STRUCTURE; BONDING; SOLUTIONS; GASES)

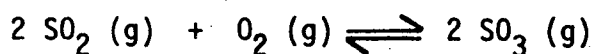
4. (a) Silicon is an element with atomic number = 14, and one particular isotope of the element has a mass number of 29.
- (i) How many protons, neutrons and electrons are there in one atom of this isotope?
(ii) Draw the arrow-in-circle notation for this atom.
(iii) What principle did you have to apply in answering (ii)?
(iv) How many valence electrons does it have? (14)
- (b) When sodium chloride dissolves in water Van der Waals' forces are formed during the process.
- (i) State what type of compound sodium chloride is, and what forces are present in the solid.
(ii) State what type of compound water is, and what forces are present between water molecules.
(iii) What are Van der Waals' forces in this case?
(iv) Write down *three* properties of Van der Waals' forces. (21)

- (c) Under the conditions present in the laboratory most gases behave as ideal gases.
- (i) What is meant by saying a gas behaves as an *ideal gas*?
 - (ii) One of the important gas relationships is $pV = k$. Name and state the law which describes this relationship.
 - (iii) Name the temperature scale used in calculations, and state the approximate value of human body temperature on this scale.
 - (iv) What is the approximate value of pressure at STP?

(15)
/50/

(ATOMIC STRUCTURE; EQUILIBRIUM; ELECTROCHEMICAL CELLS; OXIDATION-REDUCTION)

5. (a) The Group I elements tend to have low ionisation energies.
- (i) Give the name of this group, and state two members of the group.
 - (ii) What is *ionisation energy*?
 - (iii) What property of an element can be attributed to the fact that it has a low ionisation energy?
 - (iv) Name the characteristic they possess that causes them to be placed in the same group.
- (b) An important reaction during the industrial manufacture of sulphuric acid is



- (i) What is the meaning of the equilibrium sign used?
- (ii) Why is such a process called *dynamic*?
- (iii) What will be the effect on this reaction by raising the pressure?
- (iv) What principle did you use to arrive at the answer to (iii)?
- (v) An increase in temperature causes a decrease in the concentration of SO_3 . What does this tell you about the reaction?

(14)

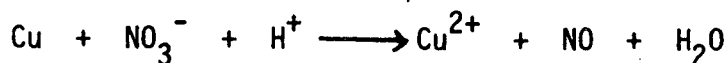
- (c) The emf of the cell based on the nett reaction



is 1,10 V.

- (i) Why does this reaction occur?
 (ii) What solution would you have in the zinc half of the cell, and what would be its concentration? (10)

- (d) Copper reacts with the nitrate ion as follows:



- (i) Balance this equation using oxidation numbers, clearly showing your working.
 (ii) Name the reducing agent in the reaction. (11)

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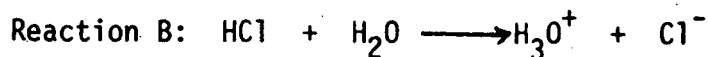
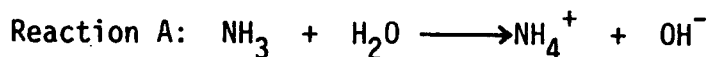
(BONDING; REACTION RATES; ACIDS; ORGANIC CHEMISTRY)

6. (a) The methane molecule (CH_4) is a good example of a covalent compound.

- (i) What is a *covalent bond*?
 (ii) What is a *molecule*?
 (iii) Describe briefly the shape of the methane molecule.
 (iv) How can you explain this shape, which is different from what would be expected? (18)

- (b) Zinc reacts with dilute hydrochloric acid to produce hydrogen. State four *specific* ways of increasing the rate of this reaction. (8)

- (c) Consider the following reactions:



- (i) In what important way do the two reactions differ?
 (ii) What property of water is illustrated in (i)?
 (iii) Using the letters a_1 and a_2 rewrite each equation showing the two Lowry-Brønsted acids in each. (10)

(d) The chemistry of carbon includes organic chemistry.

- (i) On what property of carbon does organic chemistry depend?
- (ii) What is the *atomic structure* of carbon atoms in the alkanes?
- (iii) The alkanes are saturated hydrocarbons. What does *saturated* mean?
- (iv) What is the main use of simple alkanes?

(14)
/50/
