STUDENT ATTITUDE AND ACHIEVEMENT IN FRESHMAN PHYSICS,
AS RELATED TO STATED STUDENT OCCUPATIONAL
CHOICE: A MULTIVARIATE APPROACH

by

ROGER F. FOX

B.Sc. University of British Columbia, 1959

A THESIS SUBMITTED IN PARTIAL FULFILMENT OF
THE REQUIREMENTS FOR THE DEGREE OF
MASTER OF ARTS

in the Department
of
SCIENCE EDUCATION

We accept this thesis as conforming to the
required standard

THE UNIVERSITY OF BRITISH COLUMBIA
August, 1974
In presenting this thesis in partial fulfilment of the requirements for an advanced degree at the University of British Columbia, I agree that the Library shall make it freely available for reference and study. I further agree that permission for extensive copying of this thesis for scholarly purposes may be granted by the Head of my Department or by his representatives. It is understood that copying or publication of this thesis for financial gain shall not be allowed without my written permission.

ROGER F. FOX

Department of Science Education
The University of British Columbia
Vancouver V6T1W5, Canada

Date Aug 6th 1974.
ABSTRACT

Knowledge of how different vocation-oriented groups of students respond to the classroom environment is a serious concern of an instructor in a first year college physics course -- especially those who accept the responsibility of facilitating the resolution of vocational choice determination. Knowledge about the nature of the instructor's class -- in terms of how they respond to various aspects of the teaching-learning situation -- has interpretative value in making decisions about special instructional provisions for the groups.

This thesis was an attempt to provide information about the nature of the differences between vocation-oriented groups of students, in terms of selected dependent variables, important to the instructor of a first year college physics course.

The data for the study was gathered from one class of a Physics 110 course offered at the University of British Columbia. Students in the class were divided into three groups based on vocational choice. Each of these groups were further subdivided in terms of the amount of high-school physics experience. Nineteen dependent variables were classified into three categories:

(a) **Antecedent** -- Variables which provided information on a student's general academic ability, and his competence in Science subjects at the high-school level,

(b) **Cognitive** -- Variables which provided information on student achievement during the year in Physics 110, and
(c) Affective -- Variables providing information about a student's attitude towards concepts related to science in general and physics in particular.

The data gathered was analysed first by a one-way multivariate analysis of variance. This analysis showed that there was a statistical significant difference between vocation-oriented group centroids on the dependent variables taken all at a time. The analysis was carried further to determine the nature of these group differences through a discriminant analysis. The discriminant analysis produced two significant discriminant functions which provided information on the variables that contributed most to differentiating between the groups along each function.

The overall conclusion that was suggested is that only those students who were required to take just one year of college physics were clearly distinguished from the other vocation oriented groups. The major distinction between these groups being academic ability. Years of schooling in a subject area was also an important distinguishing factor for instructional purposes, but this factor did not discriminate between the various vocation-oriented groups.
ACKNOWLEDGEMENTS

The author wishes to express his thanks to his committee: Dr. Cannon, Committee Chairman, Dr. Boldt and Dr. Westphal. Special thanks must be given to Dr. Cannon for the opportunity to do graduate work, and for all his efforts on my behalf.

The author will always be indebted to Dr. Boldt for his guidance, empathy, and patient understanding of my difficult nature. Dr. Boldt provided inspiration, and gave unstintingly of his time to ensure a successful conclusion to the study.

The author wishes to acknowledge the many others who were so willing to listen and offer advice: Dr. Bashook, Mr. Page, and Mr. and Mrs. Erickson. Without their continual urging and encouragement this work may not have been completed.

The author expresses his deepest affection to his wife Marguerite, and two children, Jennifer and Pamela, each of whom, in her own way, helped in the realisation of the value of this study.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Chapter</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABSTRACT</td>
<td>ii</td>
</tr>
<tr>
<td>ACKNOWLEDGEMENTS</td>
<td>iv</td>
</tr>
<tr>
<td>TABLE OF CONTENTS</td>
<td>v</td>
</tr>
<tr>
<td>LIST OF TABLES</td>
<td>ix</td>
</tr>
<tr>
<td>LIST OF FIGURES</td>
<td>x</td>
</tr>
</tbody>
</table>

1. THE PROBLEM AND ITS CONTEXT | 1 |
1.1 Importance of the Study | 1 |
1.2 Statement of the Problem | 4 |
1.2.1 General Problem | 4 |
1.2.2 Specific Problem | 4 |
1.2.3 Statistical Hypothesis | 5 |
1.3 Definition of Terms | 6 |
1.4 Method of Study | 6 |
1.4.1 Cognitive Variables | 6 |
1.4.2 Affective Variables | 7 |
1.4.3 Antecedent Variables | 8 |
1.5 Limitations of the Study | 9 |
2. RELATED STUDIES | 10 |
2.1 Theories of Vocational Choice | 10 |
2.1.1 Non-Developmental Theories | 10 |
2.1.2 Developmental Theories | 11 |
2.1.3 Summary | 16 |
<table>
<thead>
<tr>
<th>Chapter</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.2</td>
<td>17</td>
</tr>
<tr>
<td>2.2.1</td>
<td>17</td>
</tr>
<tr>
<td>2.2.2</td>
<td>17</td>
</tr>
<tr>
<td>2.2.3</td>
<td>18</td>
</tr>
<tr>
<td>2.2.4</td>
<td>19</td>
</tr>
<tr>
<td>2.2.5</td>
<td>22</td>
</tr>
<tr>
<td>2.3</td>
<td>23</td>
</tr>
<tr>
<td>2.3.1</td>
<td>23</td>
</tr>
<tr>
<td>2.4</td>
<td>26</td>
</tr>
<tr>
<td>2.4.1</td>
<td>26</td>
</tr>
<tr>
<td>2.4.2</td>
<td>32</td>
</tr>
<tr>
<td>2.5</td>
<td>32</td>
</tr>
<tr>
<td>2.5.1</td>
<td>32</td>
</tr>
<tr>
<td>2.6</td>
<td>34</td>
</tr>
<tr>
<td>3.1</td>
<td>36</td>
</tr>
<tr>
<td>3.1.1</td>
<td>36</td>
</tr>
<tr>
<td>3.1.2</td>
<td>37</td>
</tr>
<tr>
<td>3.2</td>
<td>39</td>
</tr>
<tr>
<td>3.2.1</td>
<td>39</td>
</tr>
</tbody>
</table>

3. METHOD OF STUDY 36

3.1 Subjects Used in the Study 36

3.1.1 Nature of the Subjects 36

3.1.2 Selection of the Subjects 37

3.2 Method of Collecting the Data 39

3.2.1 Nature of the Independent Variables 39
<table>
<thead>
<tr>
<th>Chapter</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.2.2 Method of Collecting Data on the Independent Variables</td>
<td>41</td>
</tr>
<tr>
<td>3.3 Nature of the Dependent (Criterion) Variables</td>
<td>41</td>
</tr>
<tr>
<td>3.3.1 Method of Collecting Data on the Dependent Variables</td>
<td>43</td>
</tr>
<tr>
<td>3.4 Method of Analysis</td>
<td>48</td>
</tr>
<tr>
<td>3.4.1 Data Processing</td>
<td>48</td>
</tr>
<tr>
<td>3.4.2 Testing the Null Hypothesis</td>
<td>48</td>
</tr>
<tr>
<td>3.4.3 Discriminant Analysis</td>
<td>49</td>
</tr>
<tr>
<td>4. RESULTS OF THE STUDY</td>
<td>50</td>
</tr>
<tr>
<td>4.1 Summary of Results</td>
<td>50</td>
</tr>
<tr>
<td>4.1.1 The Data</td>
<td>50</td>
</tr>
<tr>
<td>4.2 Analysis of the Data</td>
<td>53</td>
</tr>
<tr>
<td>4.2.1 Multivariate Analysis of Variance</td>
<td>53</td>
</tr>
<tr>
<td>4.3 Discriminant Analysis</td>
<td>55</td>
</tr>
<tr>
<td>4.3.1 Results</td>
<td>55</td>
</tr>
<tr>
<td>4.4 Interpretation of Results</td>
<td>58</td>
</tr>
<tr>
<td>4.4.1 Variables Contributing to Group Separation</td>
<td>58</td>
</tr>
<tr>
<td>4.5 Summary of Results</td>
<td>64</td>
</tr>
<tr>
<td>5. CONCLUSIONS</td>
<td>65</td>
</tr>
<tr>
<td>5.1 The Problem</td>
<td>65</td>
</tr>
<tr>
<td>5.2 Conclusions</td>
<td>66</td>
</tr>
<tr>
<td>5.2.1 Group Differences</td>
<td>66</td>
</tr>
<tr>
<td>5.2.2 Discriminant Analysis</td>
<td>67</td>
</tr>
<tr>
<td>Chapter</td>
<td>Page</td>
</tr>
<tr>
<td>---------</td>
<td>------</td>
</tr>
<tr>
<td>5.3 Recommendations for Further Study</td>
<td>69</td>
</tr>
<tr>
<td>BIBLIOGRAPHY</td>
<td>71</td>
</tr>
<tr>
<td>APPENDICES</td>
<td>77</td>
</tr>
</tbody>
</table>

APPENDIX A - Personal Data Sheet
APPENDIX B - Semantic-Differential Instrument
APPENDIX C - Knowledge Pre-Test
APPENDIX D - Mid-Term I Examination
APPENDIX E - Xmas Examination
APPENDIX F - Mid-Term II Examination
APPENDIX G - Terminal Examination
<table>
<thead>
<tr>
<th>Table</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>I. PERCENT OF STUDENTS INDICATING EACH VOCATIONAL CHOICE</td>
<td>38</td>
</tr>
<tr>
<td>II. DATA MATRIX</td>
<td>47</td>
</tr>
<tr>
<td>III. GROUP MEANS, STANDARD DEVIATIONS AND TOTAL SAMPLE MEANS AND STANDARD DEVIATIONS</td>
<td>51</td>
</tr>
<tr>
<td>IV. MULTIVARIATE ANALYSIS OF VARIANCE - RESULTS</td>
<td>54</td>
</tr>
<tr>
<td>V. TABLE OF LATENT ROOTS (EIGENVALUES); CHI-SQUARE TEST FOR EACH ROOT</td>
<td>55</td>
</tr>
<tr>
<td>VI. SCALED VECTORS FOR EACH DEPENDENT VARIABLE ON THE DISCRIMINANT FUNCTIONS</td>
<td>56</td>
</tr>
<tr>
<td>VII. GROUP CENTROIDS ON DISCRIMINANT FUNCTIONS I AND II</td>
<td>57</td>
</tr>
<tr>
<td>VIII. GROUP CS-1: FUNCTION I</td>
<td>60</td>
</tr>
<tr>
<td>IX. GROUP CS-2: FUNCTION I</td>
<td>61</td>
</tr>
<tr>
<td>X. GROUP RS-1: FUNCTION I</td>
<td>61</td>
</tr>
<tr>
<td>XI. GROUP RS-2: FUNCTION I</td>
<td>62</td>
</tr>
<tr>
<td>XII. GROUP U-1: FUNCTION I</td>
<td>62</td>
</tr>
<tr>
<td>XIII. GROUP U-2: FUNCTION I</td>
<td>63</td>
</tr>
</tbody>
</table>
## LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Group Centroids in Discriminant Space</td>
<td>59</td>
</tr>
</tbody>
</table>
CHAPTER 1

THE PROBLEM AND ITS CONTEXT

1.1 Importance of the Study

Classroom experience with first-year courses at the college level sometimes raises the question of whether or not special provision should be made for different groups of students taking the course. Of concern to the instructor of a required course in physics for entering college students, for example, may be the major differences between the different vocation-oriented groups in his class in terms of a number of criterion variables for the course, and to make appropriate provisions for these groups, if necessary.

When instructional programmes are being developed for use by teachers, a failure to monitor entry skills can result in a grossly inadequate match between learning needs of students and the content of instruction.¹

That the matter of vocational goals of students should be of concern to the instructor has been emphasized by Ginzberg [1951].

The educational system impinges directly and indirectly on the many aspects of the process of occupational choice determination. There are a host of problems of both philosophy and procedure which should be critically evaluated to insure that present practices contribute to, rather than depart from, the effective resolution of occupational choice.2

Educational practice should contribute not only to the general aims of education but also to specific aims such as the effective resolution of vocational choice. Thus, according to Ginzberg,3 if classroom instruction is to be effective in the resolution of occupational choice, an instructor needs to take students with different occupational goals into account. Stated more succinctly:

... technology has created a new relationship between man, his education, and his work, in which education is placed squarely between man and his work.4

Facilitating the resolution of vocational choice is an urgent matter at the first-year college level. The prerequisite courses offered at this level are immediately prior to embarking on specialized studies. As such, courses at the first-year college level often serve as choice-points at which final decisions about a vocation are made. The importance of assisting students in finalizing a vocational choice at the first year college level is emphasized by Ginzburgh [1951], Havinghurst [1953], and Super [1963]. These researchers have suggested

that, at the first-year college level, students make the most realistic decisions on life-style and vocation.

Knowledge of how different vocation-oriented groups respond to the classroom environment is a serious concern to the instructor of a first-year college course -- especially to those who accept the responsibility of facilitating the resolution of vocational choice determination. Knowledge about the nature of the differences between the various vocation-oriented groups in his class, -- in terms of how they respond to various aspects of the teaching-learning situation -- has interpretative value in making decisions about special instructional provisions for the groups.

The aim of the present study was to provide information about the nature of group differences in a first-year college physics course. Such information is intended to be useful in meeting the problem of resolving questions of vocational choice through special instructional provisions.

The following passage by Rosenburg [1957] summarizes, perhaps, the significance of the study:

The college youth of today are the occupational elite of tomorrow. On their present decisions hinge the fate of industry, commerce, politics, the professions, the arts and sciences, the educational system of the future. This then, is a particularly crucial group to study . . . the people who will occupy key positions (social) in time to come.5

1.2 Statement of the Problem

1.2.1 General Problem

The general problem investigated was the nature of major differences between a number of different vocation-oriented groups of students taking a first year college course, in terms of measures on a number of selected dependent or criterion variables deemed important to the instructor of the course.

Since educational outcomes are seldom measures against a single variable, it seemed more appropriate to look for differences among the groups by comparing their relative performance on all the selected criterion variables as an integrated whole. Commenting on this procedure, Tatsuoka noted that,

... the original variables usually stand in such a complicated pattern of intercorrelations among one another that we cannot, without danger of redundancy and inconsistency, speak of group differences with respect to each of them separately.

Thus examining a pattern of weights gives us a much more accurate account of the nature of group differences in terms of a set of variables than does looking at each variable separately with no regard for their interrelations and partly overlapping information.6

1.2.2 Specific Problem

The problem investigated, in the study, stated more specifically was the identification and description of variables which serve to

---

discriminate between groups of students defined, a priori, on the basis of stated vocational choice.

Two specific questions, related to the broader problem, were dealt with in the study:

1. Are there statistically significant differences between different vocational-choice groups on the selected criterion variables, taken as a whole?
2. Along what (possible psychologically meaningful) dimensions do these groups differ?

1.2.3 Statistical Hypothesis

1. The population centroids of the different vocation-oriented groups will not differ significantly - H0.
2. If significant differences between population centroids exist, statistically significant discriminant functions can be found which can be used to differentiate between the different vocation-oriented groups.

Tests of significance of the population centroids and the significance of discriminant functions obtained, will be carried out at levels of significance currently used in educational research, \( \alpha = 0.3 \), and 0.1.
1.3 Definition of Terms

**Vocational Choice**: The indication on the 'Student Personal Data Form' of the way by which the student anticipates earning a living upon completion of his college programme.

**Discriminant Function**: A linear combination of weighted variables which maximizes the ratio of the between-group variance and within-group variance.\(^7,8,9\)

1.4 Method of Study

All the variables used in the study were divided into three main categories.

1.4.1 Cognitive Variables

Measures of cognitive ability were an integral part of the course and were as follows:

1. **Knowledge Pre-Test** -- A test designed by the course instructor to ascertain student entry skills and physics knowledge. It was administered at the start of the course.


2. **Scheduled Examinations** -- Each of the following were constructed by the instructor using Bloom's Taxonomy\(^{10}\) of Educational Objectives: Cognitive Domain 'as a base.' They were as follows:

(a) **Mid-Term I**: Administered to all students in November 1969.

(b) **Christmas Examination**: Administered in December, 1969.

(c) **Mid-Term II**: Administered in February, 1970.

(d) **Terminal Examination**: Administered in April, 1970.

1.4.2 **Affective Variables**

The instrument used to collect affective data was developed and used by Page [1970]\(^{11}\) in the Physics Education Evaluation Project.\(^{12}\) It was an adaptation of what is known in psychological research as a Semantic Differential [Osgood, Suci, and Tannenbaum, 1957].\(^{13}\) The instrument will be described in greater detail in a later chapter.


\(^{12}\)Ibid.

1.4.3 Antecedent Variables

These variables provided information on a student's general academic ability and his ability in Physics at the High-School level.

1. Co-Operative Academic Ability Test (CAAT). This test had two components: (a) Verbal and (b) Quantitative. Scores on the two components were considered as variables in addition to the total test score. This test was administered by the University testing staff as part of the testing programme given to all freshmen students.

2. High-School Graduating Average Mark. This score was a composite of a student's final high-school graduating mark in English, Mathematics and Physics. It was computed by the Department of Education of the Province of British Columbia, and used by the Registrar of U.B.C. to determine eligibility for entry into the first year of studies at the University.

3. High-School Physics, Chemistry and Mathematics Grades. These grades were obtained from the Student Personal Data Sheet.

Student Personal Data Sheet. The data sheet (see Appendix A) was completed by every student taking the Physics course. From this sheet the vocational choice of each was ascertained in addition to the number of years -- one or two -- of High-School Physics each student had completed. These two pieces of information were used to develop the grouping of students.
1.5 Limitations of the Study

1. There was no evidence to support a claim that the findings applied to a finite population, other than the students who participated in the study.

2. All questions, on the Cognitive and Affective measures, were asked by means of a paper and pencil questionnaire. Thus, no assurance could be given that each question was interpreted consistently and without bias by all respondents.
CHAPTER 2

RELATED STUDIES

2.1 Theories of Vocational Choice

2.1.1 Non-Developmental Theories

For approximately the first half of the 20th century, studies dealing with problems of vocational choice tended to take a non-developmental approach. Vocational choice was seen as an event-in-time selection. In 1909, Parsons\(^1\) took a sort of "square peg, square hole" approach in watching a person with his choice of work. Subsequent publications by Paterson and Darley\(^2\) and Williamson\(^3\) fostered this approach to the problems of vocational choice.

In 1954, Pepinsky and Pepinsky\(^4\) published their "trait-and-factor" theory of vocational choice which, although based on a theory of individual differences,

---

\(^1\)Frank Parsons, Choosing a Vocation, Boston: Houghton-Mifflin co., 1909.


concerns itself with individual traits or factors which are believed to determine the choice of and success in an occupation. . . . It is, for the most part, a person-centered viewpoint with emphasis on personal traits. 

Pepinsky suggested that an individual, in trying to resolve his problem of job selection, appraises himself, i.e. his strengths and weaknesses. He becomes as knowledgeable as possible about the availability of jobs open to him, and that line of work which offers him the greatest potential satisfaction and success.

2.1.2 Developmental Theories

Beginning in the 1940's and with increasing emphasis during the 1950's, the conceptualization of vocational choice as a long-term, developmental process came under consideration. In contrast to the point-in-time event phenomenon, this approach views vocational choice as an on-going, comprehensive process involving many facets of interrelated behaviours during various points or stages of the individual's life.

Buehler [1933] developed a theory of life stages in which she concluded that most people go through corresponding developmental stages at similar chronological ages. These life stages have been categorized as Growth, Exploration, Establishment, Maintenance, and Decline.

---


Buehler theorized that vocational development, i.e., development toward choosing a vocation as well as other aspects of one's life, fit into these five stages.

Miller and Form [1951] described life stages from the point of view of work characteristics. They viewed vocational development as a life-long process in stages called Preparatory (awareness of work), Initial (part time jobs), Transition, Trial, Stable and Retired work periods.

Ginzberg and his associates [Ginzberg, Ginzberg, Axelrod and Herma, 1951], an economist, psychiatrist, sociologist, and a psychologist, respectively, joined forces to develop a theory of occupational choice. Their general theory is as follows:

First, occupational choice is a process which takes place over a minimum of six or seven years, and more typically, over ten years or more. Secondly, since each decision during adolescence is related to one's experience up to that point and in turn has an influence on the future, the process of decision making is basically irreversible. Finally, since occupational choice involves the balancing of a series of subjective elements with the opportunities and limitations of reality, the crystallization of occupational choice inevitably has the quality of a compromise.

Ginzberg and his associates theorized that there are three periods of occupational choice: the period of fantasy choice, governed

---


9 Ibid., p. 198.
by the wish to be an adult; the period of tentative choices beginning at about age 11 and determined largely by interests, then by capacities, and then by values; and the period of realistic choices, beginning at about age 17, in which exploratory, crystallization, and specification phases succeed each other.

Havighurst [1964]\textsuperscript{10} considers vocational development to be a life-long process. He suggests that there are six stages in one's vocational development, from childhood to old age. Within Stage Three (acquiring identity as a worker in the occupational structure), Havighurst views the "apparent confusion and lack of career decision in the minds of many college students" as "signs of the difficulty experienced in making what is understood to be a central decision about life."\textsuperscript{11}

The widely accepted work of Havighurst [1953] on the concept and measurement of developmental tasks and task behaviour has recently been adapted by Super [1963]\textsuperscript{12} to a concept of vocational developmental tasks. Super has proposed the following sequence of vocational developmental tasks:

1. Crystallizing a vocational preference.
2. Specifying a vocational preference.
3. Implementing a vocational preference.
4. Stabilizing in a vocation.
5. Consolidating status and advancing in a vocation.

\textsuperscript{10}R.J. Havighurst, \textit{Human Development and Education}, New York: Longmans Green, 1953.

\textsuperscript{11}Ibid., p. 232.

\textsuperscript{12}D.E. Super, \textit{Career Development: Self Concept Theory}, Princeton: College Entrance Examination Board, 1963,
In Super's earlier work [1957] he described vocational adjustment as an ongoing, continuous, generally irreversible process, and that it is an orderly, patterned process in life stages. Super's vocational life stages follow [1957b]:

1. **Growth** (birth to age 14). Self-concept develops through identification with key figures in family and in school; needs and fantasy are dominant early in this stage; interest and capacity become more important in this stage with increasing social participation and reality-testing.

   Substages of the Growth stage are:
   - Fantasy (4-10 years)
   - Interest (11-12 years)
   - Capacity (13-14 years)

2. **Exploration** (Age 15-24). Self-examination, role tryouts, and occupational exploration take place in school, leisure activities and part-time work. Sub-stages of the exploration stage are: Tentative (15-17 years). Needs, interests, capacities, values, and opportunities are all considered. Tentative choices are made and tried out in fantasy, discussion, courses, work, etc. Transition (18-21 years). Reality considerations are given more weight as the youth enters labor market or professional training and attempts to implement a self-concept.

---

3. **Establishment** (25-44 years). Having found an appropriate field, effort is put forth to make a permanent place in it. There may be some trial early in this stage, with consequent shifting but establishment may begin without trial, especially in the professions.

Substages of the establishment stage are:

- **Trial** (25-30 years).
- **Stabilization** (31-44 years).

4. **Maintenance** (Age 45-64 years).

5. **Decline** (Age 65 on).

In Super's newer work [1963][14] he describes crystallization of a vocational preference as a developmental task encountered typically during the early and middle adolescent years, the 14 to 18 year old period of the tentative substage. During this period the student is expected by society to begin to formulate ideas as to fields and levels of work which are appropriate for him; self and occupational concepts which will enable him to make tentative choices, to commit himself to a type of education or training which will lead him toward some partially specified occupation.

In addition, Super and Bachrach [1957] note that there is a social systems theory which:

---

... places emphasis upon the dynamic interaction of the individual with the social systems which impinge on him, and upon the interaction of these social systems with one another ... based on the concept of developmental tasks which confront the individual with a need to make certain ... Vocational development is thus seen as essentially a compromising or synthesizing interaction between the individual and the social systems in which he operates. 15

Substantial contributions were made to occupational choice theory by Ann Roe [1956]16 in her The Psychology of Occupations and subsequent writings.

Roe looks upon the individual, as does Maslow, as an 'integrated organized whole,' whose classification should be based upon his goals or needs, whether conscious or unconscious. Thus Roe sees an occupation as a primary source of need satisfaction. In an apparent attempt to come to some immediate closure, she seeks to arrange these goals or needs in an hierarchy of pre-potency and makes what appears to be a somewhat arbitrary choice of Maslow's somewhat arbitrary hierarchical system.17

2.1.3 Summary

There are a profusion of theories dealing with vocational choice. Most of the theories reviewed have suggested that occupational choice is a process lasting over a period of time. Many factors enter into the process, making it complex. It is significant to note that most tend to agree on the age at which vocational commitments are made.


This age usually coincides with the entry of a student to college or university.

2.2 Student Characteristics and Vocational Choice

2.2.1 Educational Interests of the Student

The pattern of interests which develop in a student over a period of time has been considered a basis for career choice. Miller and Thomas [1966] suggested that for college students, educational interests may be significantly related to their vocational interests. The highest correlation they obtained were between the physical sciences, engineering and industrial arts and expressed student interests. The lowest correlations obtained were between fine arts and the social sciences and the logically related vocations. Based on this study, it appears that educational interests may be related to several vocational interests and a vocational interest may encompass several educational interests.

2.2.2 Abilities of the Student

A conflict arises in such studies. The abilities of the student are as important as their interests and may prove to be as significant, if not more so. Wolfe and Oxtoby [1952] investigated


the ability of graduates in a number of vocations. Based on scores from the Scholastics Ability Test, they found that the average scores of students in engineering, languages, physical sciences, and psychology were higher than the college average; those of the biological sciences, social sciences and arts majors were about equal; while those graduating in agriculture, commerce, and education were below this average.

Thus ability combined with interest complicates the picture. An attempt was made to correlate the two in a study by Marshall and Simpson [1943]. They suggested that:

1. Students with definite vocational interests and choices rank relatively low in I.Q., but academic performance is mediocre and high.

2. Students with tentative vocational choices rank high in I.Q. and in grades.

3. Students who are undecided rank mediocre or low in I.Q. with academic performance usually low.

2.2.3 Values Held by the Student

Closely related to interests are the values a person holds about life, work, and scientific pursuits. Rezler [1960] examined


21 Ibid.

the values of under-achievers with those of achievers. The main concern was to determine whether or not a lack of achievement resulted from having 'wrong values,' or not carrying beliefs or values into action. He stated his findings thus:

In order to achieve in College, they (students) would need to have more compelling values than living up to the Joneses and making money; they would need to believe in self-expression, independence, and hard work, self-discipline and making one's own decisions. Commitment -- whether active or passive -- has far reaching consequences for the student's college career. 23

A number of investigators notably Cooley [1958]24 have attempted to identify personal characteristics of students at various grade levels which would assist in predicting vocational choice. In addition some of these investigators combined environmental aspects of the school, and family and occupational characteristics with personal attributes in an effort to obtain as global a picture as possible.

2.2.4 Personality of the Student

Astin [1967]25 used 26 measures of personal characteristics, three measures of school environmental characteristics and a number

23 Ibid.

of variables relating to socio-economic status, and occupational planning. She used a multiple discriminant analysis, and summarized her findings:

Seniors choosing careers in sciences show an interest in the physical sciences, linguistics, and obtain higher scores on reading comprehension than those subjects aspiring to other occupations ... to score high on the Mature Personality Temperament Scale, to possess more information about literature. ... The business group tends to score high on the business-management interest scale and literature information and to score high on the English Total variable. For the teaching group, the social service and literature-linguistic interests appear to be the best predictors. High scores on physical information and a career choice of engineering at the ninth grade level are negative predictors of a career choice of teaching at the 12th grade level.26

The importance of personality factors in vocational choice is well established [Roe, 1956],27 Seigleman and Peck, [1960]28 Tiedeman and O'Hara, 1963].29 Elton [1967]30 investigated the influence of personality and ability predictors in the selection of career roles and vocational choices. Elton used the Omnibus Personality Inventory, the composite American College Test and performed a step-wise multiple-discriminant analysis. Elton found that the personality characteristics

26 Ibid.
of students who were undecided as to their vocational choice were:

1. They enjoy independence.
2. Had less ability than those who were vocationally more committed. (The Engineering-Agriculture-Technology oriented students showed a greater interest in science and problem-solving).
3. They tend to withdraw from social contacts and responsibility.

Students choosing the field of Business and Finance appeared to be tolerant of ambiguity and non-authoritarian.

Students choosing vocations in the Arts-Humanities expressed a low interest in science and problem-solving but admitted to being anxious and having more adjustment problems. Essentially Elton found that:

It would have to be assumed that freshmen are at the stage of development in which the choice of vocation is a realistic concern in their struggle for adult status.31

. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .

. . . relationships found are far more complex than originally postulated.32

A study by Stienberg [1955]33 attempted to find answers to two questions: (a) what pattern of scores for students emerged from --"three measures of personality"and (b) were there any significant differences

---

32 Ibid.
in personality patterns among these students who were majoring in different fields. He summarized the differences as follows:

Chemistry and Mathematics: These two sub-groups show similar tendencies on all factors. Scientific, mechanical, and quantitative activities or attitudes are valued most by the men specializing in these subjects. Their most pronounced aversions are for aesthetic, business contact, and social service activities. Direct communication with people does not seem to interest these students to any appreciable extent.

Biochemistry and Psychology: The common bond between them (the sub-groups) is the merging of scientific attitudes with an interest in helping people. ... Both groups show a stronger interest in prestige and power than might have been expected. ... 34

2.2.5 Summary

While the evidence indicates that numerous factors play an important role in vocational choice, Mallinson [1969] undertook a study on factors affecting college achievement in which he included vocational choice. He, however, came to the conclusion that:

The two most significant factors related to overall achievement in College were the student's I.Q. and his belief that his parents thought education was important. With respect to the election of, and achievement in, Science courses, an influential factor, in addition to the two above, was the number of Science courses taken in Hsgh School. Interest in Science as indicated by the Kuder Preference Record during College seems to have little influence since many of those who majored in Science did not evidence interest on the test. 36

---

36 Ibid.
2.3 Self-Concept and Vocational Choice

2.3.1 Importance of Vocational Self-Concept

The term "vocational self-concept" has been used by Super [1963] to denote the

... constellation of self attributes considered by the individual to be vocationally relevant whether or not they have been translated into a vocational preference. 37

The vocational development process, briefly summarized by Super [1963] is that

In expressing a vocational preference, a person puts into occupational terminology his idea of the kind of person he is; that in entering an occupation, he seeks to implement a concept of himself; that in getting established in an occupation he achieves self-actualization. The occupation this makes possible the playing of a role appropriate to the self concept. 38

It is generally accepted in the American culture that social and economic status depend more upon one's occupation than upon anything else. Roe [1956] has stated that

entering upon an occupation is generally seen in our culture as a symbol of adulthood, and an indication that a young man or woman has reached a stage of some independence and freedom. 39

Roe feels that occupations are of extreme importance as a source of need satisfaction.

Beardslee and O'Dowd [1962, p. 607] attributes the pressures toward early vocational choice to the fact that:

... student's perceive occupations largely in terms of their implications for a style of life and a place in the community status system, and the importance of occupations in the formation of an identity. 40

The authors further state that:

For students, the occupation even specifies the personal qualities of its present and future members, providing a readymade personality for those who cannot establish a secure identity from their own experience. 41

Beardslee and O'Dowd [1962] feel that the lack of an identity "manifests itself in a purposelessness and unwillingness to be productive, an inability to commit oneself to anyone or anything."

Katz and Sanford [1962] have observed that freshmen who

... arrive at College with a concrete proposal concerning a course of study leading to some vocational goal can easily be 'talked out' of their plan; many have been under pressure to say what they are going to do or to be so that they have made superficial choices that were not in accord with their genuine needs or interests. 42


They feel that most students do not have sufficiently developed interests, especially when it comes to planning a long term course of study.

Vocational self-concept, as a component of total self-concept may also be a factor in the achievement of College students. Erikson [1950]\(^{43}\) states that it is primarily the inability to settle on an occupational identity that disturbs young people.

Truman [1964] believes

... a College must be concerned about the level and sources of student anxiety, since a deeply troubled young man is unlikely to be a good student. 44

and furthermore that at least a portion of this anxiety derives from the uncertainty of career decisions. Raushenbush [1964] related that

You have to belong somewhere before you can be something or do something ... this need was a cause of ... 'deepest anxiety.' 45

The relationship between anxiety and achievement has been investigated by Spielberger and Weitz [1964] who report that:

... anxious college students earned lower grades and on long-term follow-up, had a higher dropout rate due to academic failure than non-anxious classmates of comparable ability. 46

---


\(^{46}\) C.O. Spielberger and H. Weitz, "Improving the Academic Performance of Anxious College Freshmen," Psychological Monographs 78, (13), No. 590, 1964, p. 11.
However, they also add that there is little evidence that personality problems are direct and immediate causes of poor academic performance. Spielberger and Weitz [1964] believe that it is more likely that:

... in response to the pressures of College life, students with personality problems are pre-disposed to develop maladaptive study habits and attitudes which in turn, interfere with the learning process and lead to underachievement. 47

2.4 Academic Achievement and Vocational Choice

2.4.1 Importance of Academic Success

The literature on the College student tells us that a substantial proportion of able students leave College before graduation.

The studies of students pile up evidence that too many of our students work casually... drift in the College or drift out. 48

These studies report that the proportion varies from College to College with attrition rates fluctuating from twelve percent to eighty-two percent [Iffert, 1958; 49 Sanford, 1962; 50 Wise, 195851]. Something is obviously wrong on the College campus. We need to know more about the personal characteristics of students that are

of significance for learning, and we need to know more about the various kinds of educational experiences which influence students' growth and development. Many authors are in agreement that

We have yet to succeed in identifying, for the majority of College students, the principal factors which are related to academic success. 52

Literally hundreds of studies have been completed in recent years on the topic of predicting success in College, Sanford [1962]. 53 An extensive review of academic achievement by Endler and Steinberg [1963]54 and of underachievement by Peterson [1963], 55 both came to the conclusion that "The only consistent finding has been that there are no consistent results."

Summerskill [1962], 56 in a recent review, reported that vocational motivation is demonstratably related to attrition. He found that students with definite vocational choices are more likely to be overachievers in College, but not at all Colleges. Similarly, students with definite vocational choices are more likely to graduate from College, although this also has not been a universal finding. He considered it noteworthy that the majority of students could report a

---

52 Ibid., p. 22.
53 Ibid.
"definite" or "probably" vocational choice early in their College careers.

In another review, Beardslee and O'Dowd [1962] point out that, on a national scale, there is evidence that vocationally oriented students are more likely to succeed in College "both from a psychological and an academic point of view." They also conclude that freshmen who are undecided about their occupational future "will contribute disproportionately to the dropouts in ensuing years." 

A number of authors have recently expressed similar viewpoints on the relationship of an early vocational decision and academic success in College. A study at New York University reported by Coleman [1960] found that students who settled on their career goals during their first year of College fared better than those who decided later. The survey also discovered that, on the average, these students wind up earning higher salaries and are more likely to remain in their fields. Hilgard [1953] stated that

... with the vocational objective left out or postponed for the future, general education is likely to lead either to dilettantism or to that degeneration of College life which makes everything else seem more important to the student than the classroom. 

Ibid.  
J.C. Coleman, Success in College, Chicago, Scott, Foresman, 1960.  
Ibid.
Vineyard [1964] believes that College freshman without an educational goal will see

... little practicality in the courses on their study programs, be poorly motivated to achieve and, unless a choice is soon made, will become dropouts. 62

Sanborn [1965] recently came to the conclusion that:

... as a rule, those who could envision the long-range outcomes of College ... those who could specify reasonably well the vocational goals they expected to reach -- worked successfully during their first semester in College. Those who had no particular expectations concerning what they wanted to do after they graduated, as a rule, worked unsuccessfully. 63

The implication that College freshmen should have a "fixed aim" is questionable in view of the evidence that the selection of a vocation is not a single choice, but rather a process that takes place over a number of years, Ginzberg [1951], 64 Super [1957]. 65


Iffert [1958] found that in general:

Students who reported a change in subject-field of interest had a higher graduation percentage than did students who maintained their interests in subject-fields distinctly occupational in character and had the highest persistence and graduation rates. Change in interest from the academic to the practical, combined with the higher graduation rate of those who change and of those who adhere to practical subject-fields suggests that occupation-centered interests promote persistence in College. 66

Ford and Urban [1965] reporting on a study of College students at the Pennsylvania State University, speculate that:

... highly flexible University structures within which bright students can make one commitment and then another until they hit pay dirt, is the most conducive to the graduation of bright students. 67

In the above study, an examination of graduation rates in relation to the frequency with which students transferred among the ten Colleges within the Pennsylvania State University revealed the following graduation rates: one change, 40 percent; two changes, 78 percent; and three or more changes, 91 percent. Of the students who made no change in College, 62 percent earned degrees. Ford and Urban found that students who made two, three, or more changes had higher scholastic aptitude scores than those who made no change or only one change.

The desirability of early vocational choice as a means of assuring academic success in College has recently been challenged. Chervenik [1965] stated that: "a firm commitment at College entrance is . . . not necessary, and even may be undesirable." She feels that . . . deferring vocational decisions may free the student from anxiety and allow him to profit by application to learning, rather than suffer an overly pragmatic concern of: Where will it lead vocationally? 68

Tucci [1961]69 discovered a trend indicating that vocationally undecided students were actually superior to definitely decided students in regard to clarity of self-concept. And Thompson [1966],70 in a study of student commitment to a specific discipline at the University of California at Davis, found that in general, committed students tended to earn lower grades and also tended to have lower verbal and mathematical ability than the uncommitted student. The committed student was also observed to follow a certain behaviour pattern. He appears to be traditionally oriented, dedicated, hard-working, and task centered, according to Thompson.


2.4.2 Summary

The reviewed studies suggest that the student most likely to achieve the highest grades in College and remain to graduate, is the one who has some vocational goal in mind when he enters College, but who has not committed himself to a specific vocation. However, the vocationally committed student may be inflexible in his ability to change programmes, and more traditionally oriented.

2.5 Secondary School Achievement and Vocational Choice

2.5.1 Importance of Secondary School Achievement to Success in College

Past and present research indicate agreement that the "... evidence is quite clear that achievement in high school is the best single predictor of College success."

A study by Altman [1959], and a review by Travers [1949], of over 200 prediction studies, support the conclusion that

... average high school grades surpass either subject-matter or psychological tests as predictors of College Grades. 74

---


This conclusion is further supported by Fishman\textsuperscript{75} who concluded that high school grades not only predict College freshman grades but also rank among the best predictors of future College achievement.

The reliability of the grade average as a predictor may be challenged as it is based largely on subjective judgements by teachers. However, Bloom and Peters\textsuperscript{76} report that, in certain instances, these grade averages may have a reliability coefficient as high as +0.85. In addition they suggest that the judgements of high-school teachers correlate highly with the judgements of College instructors and with College achievement.

A study by Adkins\textsuperscript{77} on students who had graduated from a high-school and were attending University showed a correlation coefficient of 0.46 between high-school grade point average and their College freshmen grade point average. Michael and Jones\textsuperscript{78} found that high-

\textsuperscript{74} Ibid.

\textsuperscript{75} J.A. Fishman, "Social-Psychological Theory for Selecting and Guiding College Students," \textit{American Journal of Sociology} 61, 1966, pp. 472-484.


school achievement was a better predictor of College grades than either the part or total scores of the Scholastic Aptitude Test.

A predictive study at a small southern College, using high-school rank, SAT, SCAT, and Comparative English Test scores, by Vick and Homaday showed that the high-school rank and the score on the Comparative English Test were the best predictors of College academic achievement.

2.6 Conclusions

Colleges and Universities are playing a critical role in the preparation of young people for a vocation in their adult life. Education is a primary variable which determines an individual's role in society. As a consequence a greater understanding of the student and of the educational process.

The preceding review of the significant literature on the Theories of Vocational Choice; Student Characteristics and Vocational Choice; Self-Concept and Vocational Choice; Academic Achievement and Vocational Choice; Secondary School Achievement and Vocational Choice; was an attempt to relate the present investigation to relevant studies. These studies make it clear that many variables in an educational setting affect the student at any one time. These studies also suggest a need to investigate the problem of the relative importance of these variables in relation to teaching and learning of students engaged in

the process of resolving the problem of vocational choice.

Multivariate analysis has the advantage over conventional univariate procedures in that group differences on a given set of variables are more interpretatible because interrelationships between the variables are taken into account. Usually, the variables stand in such a complicated pattern of intercorrelations among one another that it is impossible, without the danger of redundancy and inconsistency, to interpret group differences with respect to each of them separately. Discriminant functions obtained by multivariate analysis of variability between students on a set of variables, on the other hand, are uncorrelated with one another and this fact makes it possible to interpret the differences and resemblances between the groups more consistently.

Some of the studies described above (notably those of Cooley [1958] and Elton [1967]) used multivariate analysis. In each case different variables were used. The present study is based on a set variables presumed to be directly related to the educational outcomes of a course of instruction and thus constitute an attempt to relate the educational process in a specific course to problems of vocational choice.
CHAPTER 3

METHOD OF STUDY

The following sections of this chapter deal with the subjects used in the study, methods of collecting data about the subjects, and the method of analyzing the data used.

3.1 Subjects Used in the Study

3.1.1 Nature of the Subjects

Students entering the University of British Columbia take a first year physics course as an elective or required course. Three types of physics courses are offered: (a) Pre-honours physics course for students electing a science and/or a mathematics honours course of studies -- Physics 120, (b) Physics 110 for those students requiring physics for a particular course of studies, e.g. Medicine, and who have had some high-school physics, and, (c) Physics for those students who have had no high-school physics, but require a first year physics course -- Physics 115.

Since students who register in Physics 110 have varying backgrounds in high-school physics and tend to seek varied vocational goals, it was decided that Physics 110 students constitute the subjects of the study.

Three sections of Physics 110 were offered in the Physics Department at the University of British Columbia at the time of this investigation. The criteria used by students in choosing a particular
section of the course was, as far as could be determined, based on convenience.

The total enrollment for Physics 110 in 1969-1970 was 992. Section 1 contained 382 students, Section 11-425 and Section 111-185.

The academic ability of the students in each section, as measured by the Co-operative Academic Ability Test, was very nearly the same. The mean scores were: Section 1-72.6, Section 11-70.4, and Section 111-73.4. The proportion of students in each section indicating the various vocational choices listed on the Personal Data Sheet are given in Table 1.

3.1.2 Selection of the Subjects

All the subjects in Section 1 of Physics 110 were used in the study. The selection was based on criteria of convenience. The basis for selecting Section 1 were:

1. The instructor was willing to participate in the study of the extent of:
   (a) Developing a carefully considered rationale for the course.
   (b) Cooperating in the construction of suitable instruments to obtain measures on the criterion variables established for the course.¹

2. The data necessary for this study was readily available.

### TABLE I

**PERCENT OF STUDENTS INDICATING EACH VOCATIONAL CHOICE**

<table>
<thead>
<tr>
<th>Vocational Choice</th>
<th>Section I</th>
<th>Section II</th>
<th>Section III</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engineering</td>
<td>15.50%</td>
<td>20.00%</td>
<td>14.78%</td>
</tr>
<tr>
<td>Physics</td>
<td>1.20</td>
<td>0.70</td>
<td>0.98</td>
</tr>
<tr>
<td>Bio-Sciences</td>
<td>7.87</td>
<td>7.12</td>
<td>9.51</td>
</tr>
<tr>
<td>Medicine</td>
<td>12.80</td>
<td>11.40</td>
<td>11.32</td>
</tr>
<tr>
<td>Pharmacy</td>
<td>2.48</td>
<td>3.30</td>
<td>2.95</td>
</tr>
<tr>
<td>Teaching</td>
<td>3.37</td>
<td>3.70</td>
<td>4.43</td>
</tr>
<tr>
<td>Geology</td>
<td>2.03</td>
<td>1.64</td>
<td>0.98</td>
</tr>
<tr>
<td>Forestry</td>
<td>2.48</td>
<td>3.30</td>
<td>3.94</td>
</tr>
<tr>
<td>Undecided</td>
<td>26.30</td>
<td>28.80</td>
<td>30.00</td>
</tr>
</tbody>
</table>

**Note:** Table 1 shows that the three sections of Physics 110 were quite similar in the vocational choices indicated.
3.2 Method of Collecting the Data

3.2.1 Nature of the Independent Variables

Students were asked to indicate years of high-school physics taken, their occupational choice, and their educational background in science. Based on these responses, the students were divided into six groups, each group representing a category or an independent variable of the study.

The basis for grouping were as follows:

1. Indicated occupational choice.
2. The number of years of university physics the student would have to take in pursuit of the vocation chosen. This was determined through consultation with the University Calendar, 55th Session, 1969-1970, and counsellors in various departments at the university.
3. The number of years of high-school physics taken.

The categories or independent variables were determined as follows:

(a) **Cardinal Science**: All students whose vocational goals could be included in the following subject-matter areas: Engineering, Physics, Chemistry, Mathematics, Geology, and Meteorology. Each of these areas of study require students to undertake more than one year of study in university physics.

Subjects in this area were further subdivided into two sub-categories based on (3) above; i.e. subjects with
one year of high-school physics and subjects with two years of high-school physics.

(b) Undecided: This category included all subjects who indicated that they were undecided as to vocational goal. This category was further subdivided according to (3).

(c) Required Science: This group included subjects whose indicated vocational goals were: Forestry, Agriculture, Teaching, Home-Economics, and Medicine. These occupational areas require only one year of University Physics -- usually in the freshman year. This category was also subdivided into two groups according to (3).

The classification procedure described above was based largely on the Course Rationale\(^2\) which identified three categories of students for whom the course was specifically planned:

(a) Students whose future work depends on knowledge of physics methods and facts. . .
(b) Students whose future work depends to some extent on knowledge of physics methods and facts. . .
(c) Students whose future work will, if at all be only indirectly related to physics. . . \(^2\)

3.2.2 Method of Collecting Data on the Independent Variables

The Personal Data Sheet used in this research consisted of a single page questionnaire of the self-report type. (A sample can be found in Appendix A).

In regard to self-report instruments, Froehlich and Darley\(^3\) conclude that:

1. Self-report documents have reasonably satisfactory levels of validity, reliability, and use, especially if the student's responses are given careful consideration.
2. Students will consistently and accurately report the facts concerning themselves if conditions are favourable. \(^4\)

The students were asked to complete the Personal Data Sheet at the start of the academic year. Student responses to the questionnaire constituted data on the independent variables of the study.

3.3 Nature of the Dependent (Criterion) Variables

The dependent variables used in this study fall into three groups; (a) Cognitive, (b) Attitudinal, (c) Antecedent.

(a) Cognitive: Measures on cognitive variables were obtained by means of regular tests and examinations that were given by the instructor during the course. They include the


\(^4\)Ibid.
Mid-Term Tests, First Term Test, and the Final Examination. A pre-test was given at the year's start, and served as a measure of background knowledge of physics, prior to the course.

(b) Attitudinal: Measures on attitudinal variables were obtained by Page [1969]. Based on a Semantic Differential type of instrument developed by Osgood, Suci, and Tannebaum [1957] these measures represented indicants of attitude toward selected concepts related to the Physics 110 course (e.g. Physics, Problem Solving, Natural Phenomena, etc.). The instrument can be found in Appendix B.

(c) Antecedent: Measures on antecedent variables important to achievement in the course, such as academic ability, high-school physics achievement, and high-school mathematics and chemistry achievements were obtained from a number of sources. The Cooperative Academic Ability Test was administered by the University Counselling Services, and, according to the Educational Testing Service

... measures skill in handling certain specific kinds of verbal and mathematical material -- performance which bears a rather high relationship to school achievement. 7

5 G. Page, Doctoral Candidate, Science Education, Faculty of Education, University of British Columbia.


7 Educational Testing Service, Cooperative Test Division, California, 1967.
3.3.1 Method of Collecting Data on the Dependent Variables

Cognitive Dependent Variables:

1. **Knowledge Pre-Test**: This test was designed with the main objective of providing the instructor with information on student subject matter preparation. A multiple-choice format was used. Bloom's Taxonomy of Educational Objectives (Cognitive Domain)\(^8\) provided the basis for developing the items of this test.\(^9\) This test was administered to the population at the start of the academic year.

2. **Course Examinations**: Four examinations were administered to the experimental group;
   (a) Mid-Term I, November, 1969.
   (b) Xmas, December, 1969.
   (c) Mid-Term II, February, 1970 and
   (d) Terminal Examination, April, 1970.

   Each of these examinations was administered under the rules and regulations set out by the University.

   Bloom's Taxonomy of Educational Objectives Cognitive Domain was used as a guide to ensure that the various levels (memory, comprehension, application, analysis, and synthesis) were adequately represented.\(^{10}\) Each of the

---


questions were subjected to judgement as to the level the question represented.

These examinations provided a measure of individual cognitive achievement during, and at the end of, the Physics 110 course.

Each instrument can be found in Appendices C, D, E, F and G.

Attitudinal Variables

An adaption of the Semantic Differential [Osgood, Suci, and Tannebaum, 1957] designed and administered by G. Page [1969], was used to gather data on the amount of favorableness toward or against objectives culled from the Course Rationale, e.g. Intellectual Excitement. The rating scales used were descriptive word-pairs: important -- unimportant: valuable -- worthless; rewarding -- unrewarding, and so on (see Appendix B). These ratings constituted the data used for analysis.

The concepts presented to the student for rating were selected on the bases of:

1. Emphasis given in the Course Rationale. For example, Intellectual Excitement was mentioned and stressed in the Rationale as a hoped-for course outcome.

10W. Westphal, Results of the Physics Education Evaluation Project - Final Report, Physics Department, University of British Columbia, 1970.
2. Importance as an aspect of the course to which course objectives would be related. The concept, Natural Phenomena, for example, represented such an aspect of the course.

3. Importance as a major external factor which could influence the attainment of course objectives. My Previous Physics Course is an example of an objective of this kind.

The descriptive word-pairs used in connection with the rating scales were selected as follows:

1. Adjectives or adjectival phrases were chosen which described how the instructor thought the students would perceive the course objective. Each word or phrase selected was matched with an appropriate antonym to provide word or phrase-pairs.

2. Twelve word-pairs were selected from the evaluative, potency, and activity dimension lists in Osgood's work for use as a reference in facilitating interpretation of the scales developed for the present evaluation study.11

The concepts used were: Physics, Problem Solving, Natural Phenomena, Intellectual Excitement, My Previous Physics Course, My

---

Antecedent Dependent Variables

These variables were entry skills, academic ability, and student background knowledge. Data on these variables were obtained as follows:

1. From the Personal Data Sheet, achievement in High-School Physics, Chemistry, and Mathematics was obtained.

2. The Cooperative Academic Ability Test administered by the University Student Services provided:

   ... measures of skill in handling certain specific kinds of verbal and mathematical material -- performance which bears a rather high relationship to school achievement. 12

3. The High-School graduating averages of each student, as computed by the Department of Education of British Columbia, was obtained through the University of Student Services Department.

   This average mark was computed from final grades obtained in English, Mathematics, Physics, and one other science.

Table II gives a summary of the kinds of data collected in the form of a data matrix.

# TABLE II

## DATA MATRIX

<table>
<thead>
<tr>
<th>DEPENDENT VARIABLES</th>
<th>GROUPS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cardinal Science</td>
</tr>
<tr>
<td></td>
<td>One Year (N=62)</td>
</tr>
<tr>
<td>Knowledge Pre-Test</td>
<td></td>
</tr>
<tr>
<td>Mid-Term I</td>
<td></td>
</tr>
<tr>
<td>Xmas</td>
<td></td>
</tr>
<tr>
<td>Mid-Term II</td>
<td></td>
</tr>
<tr>
<td>Terminal Examination</td>
<td></td>
</tr>
<tr>
<td>Physics</td>
<td></td>
</tr>
<tr>
<td>Problem Solving</td>
<td></td>
</tr>
<tr>
<td>Natural Phenomena</td>
<td></td>
</tr>
<tr>
<td>Intellectual Excitement</td>
<td></td>
</tr>
<tr>
<td>My Previous Physics Instructor</td>
<td></td>
</tr>
<tr>
<td>My Previous Physics Course</td>
<td></td>
</tr>
<tr>
<td>My Expectations for Physics 110</td>
<td></td>
</tr>
<tr>
<td>Verbal Component</td>
<td></td>
</tr>
<tr>
<td>Academic Component</td>
<td></td>
</tr>
<tr>
<td>Quantitative Ability</td>
<td></td>
</tr>
<tr>
<td>Test</td>
<td></td>
</tr>
<tr>
<td>High-School</td>
<td></td>
</tr>
<tr>
<td>1. Ph. Grade</td>
<td></td>
</tr>
<tr>
<td>2. Chem. Grade</td>
<td></td>
</tr>
<tr>
<td>3. Math. Grade</td>
<td></td>
</tr>
<tr>
<td>4. High School</td>
<td></td>
</tr>
<tr>
<td>Graduating</td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td></td>
</tr>
</tbody>
</table>
3.4 Method of Analysis

3.4.1 Data Processing

All data was punched onto IBM cards and checked by the University Centre Keypunch operator service. Each punched card contained a student identification number, group classification and the scores on all variables.

3.4.2 Testing the Null Hypothesis

Multivariate analysis of variance procedures were used to analyse the data and to test the null hypothesis of the study, stated in statistical form as follows:

\[ H_2 : \mu_1 = \mu_2 = \mu_3 \cdots = \mu_k \]

where the centroid of the \( j \)th group is given by:

\[ \mu_j = (\mu_{j1}, \mu_{j2}, \mu_{j3}, \cdots, \mu_{jm}, \cdots, \mu_{jp}) \]

\( m = 1, 2, 3, \cdots, p \), dependent variables.

The null hypothesis was tested at the \( p = 0.03 \) level of significance. This value was chosen on the basis of current educational practice.
Using a one-way, fixed effects multivariate design, the Cooley and Lohnes\textsuperscript{13} computer programme -- $H_1 : H_2$ -- was applied to the data, and a test of the null hypothesis made.

3.4.3 Discriminant Analysis

Since the population centroids for the six different vocational-choice groups were found to differ significantly on the nineteen dependent variables taken simultaneously, a study of group differences in terms of performance on a set of nineteen dependent variables was undertaken. The method used was a discriminant analysis. The computer programme used for this purpose was DISCRIM.\textsuperscript{14} This programme yielded additional information such as:

1. Chi-square tests on each discriminant function.

2. A cross-check on the data generated by the Cooley and Lohnes\textsuperscript{15} programme.

The results and conclusions of the study are given in the following chapters.


\textsuperscript{15}Cooley, \textit{op. cit.}. 
CHAPTER 4

RESULTS OF THE STUDY

In order to answer the questions in Section 1.1.2 of Chapter 1, multivariate and discriminant analyses on the data collected were carried out. The results obtained and an interpretation of the results are presented in this chapter.

4.1 Summary of Results

4.1.1 The Data

Table III presents a summary of the group sizes, group means, group standard deviations, and the total sample size, mean and the standard deviation, on each dependent variable.

Examination of Table III showed that the mean scores for groups CS-2, RS-2, and U-2, seem consistently higher on each cognitive dependent variable than those for groups CS-1, RS-1 and U-1. The same pattern does not appear evident for any other group of variables, i.e. the Antecedent or Affective dependent variables. However, in some cases, e.g. CAAT, the mean scores for groups RS-2 and U-2 appear noticeably higher than those for RS-1 and U-1. These patterns in mean scores made a further analysis necessary. The results of these analyses are outlined in the following sections of the Chapter.
### TABLE III

**GROUP MEANS, STANDARD DEVIATIONS AND TOTAL SAMPLE MEANS AND STANDARD DEVIATIONS**

<table>
<thead>
<tr>
<th>Variables</th>
<th>CS-I N=63</th>
<th>CS-II N=56</th>
<th>RS-I N=91</th>
<th>RS-II N=48</th>
<th>UI N=66</th>
<th>U-II N=58</th>
<th>Total Sample N=382</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>M</td>
<td>SD</td>
<td>M</td>
<td>SD</td>
<td>M</td>
</tr>
<tr>
<td>CAAT</td>
<td>73.54</td>
<td>8.13</td>
<td>70.55</td>
<td>13.43</td>
<td>70.24</td>
<td>13.37</td>
<td>73.17</td>
</tr>
<tr>
<td>VC</td>
<td>33.79</td>
<td>6.07</td>
<td>32.21</td>
<td>8.39</td>
<td>33.25</td>
<td>6.50</td>
<td>31.41</td>
</tr>
<tr>
<td>QC</td>
<td>33.78</td>
<td>4.33</td>
<td>38.34</td>
<td>7.19</td>
<td>40.75</td>
<td>4.29</td>
<td>38.83</td>
</tr>
<tr>
<td>HSC</td>
<td>2.11</td>
<td>0.90</td>
<td>2.26</td>
<td>0.98</td>
<td>2.10</td>
<td>0.93</td>
<td>2.18</td>
</tr>
<tr>
<td>HSM</td>
<td>2.51</td>
<td>0.96</td>
<td>2.57</td>
<td>0.99</td>
<td>2.73</td>
<td>0.94</td>
<td>2.57</td>
</tr>
<tr>
<td>HSGA</td>
<td>70.63</td>
<td>7.37</td>
<td>69.91</td>
<td>6.18</td>
<td>70.35</td>
<td>6.26</td>
<td>68.83</td>
</tr>
<tr>
<td>MT-I</td>
<td>28.75</td>
<td>7.74</td>
<td>27.27</td>
<td>8.52</td>
<td>31.46</td>
<td>8.13</td>
<td>28.17</td>
</tr>
<tr>
<td>XM</td>
<td>65.63</td>
<td>15.15</td>
<td>59.90</td>
<td>17.07</td>
<td>70.87</td>
<td>16.88</td>
<td>66.98</td>
</tr>
<tr>
<td>MT-II</td>
<td>34.87</td>
<td>6.20</td>
<td>32.74</td>
<td>6.91</td>
<td>36.27</td>
<td>8.50</td>
<td>33.68</td>
</tr>
<tr>
<td>TE</td>
<td>66.92</td>
<td>13.99</td>
<td>60.41</td>
<td>15.21</td>
<td>67.02</td>
<td>13.55</td>
<td>65.89</td>
</tr>
<tr>
<td>Ph</td>
<td>0.20</td>
<td>0.58</td>
<td>0.18</td>
<td>0.52</td>
<td>0.26</td>
<td>0.63</td>
<td>0.30</td>
</tr>
<tr>
<td>PS</td>
<td>0.09</td>
<td>0.58</td>
<td>0.12</td>
<td>0.52</td>
<td>0.20</td>
<td>0.51</td>
<td>0.34</td>
</tr>
<tr>
<td>NP</td>
<td>0.22</td>
<td>0.66</td>
<td>0.29</td>
<td>0.52</td>
<td>0.33</td>
<td>0.54</td>
<td>0.21</td>
</tr>
<tr>
<td>IE</td>
<td>0.68</td>
<td>0.63</td>
<td>0.65</td>
<td>0.54</td>
<td>0.61</td>
<td>0.69</td>
<td>0.67</td>
</tr>
<tr>
<td>PPI</td>
<td>-0.46</td>
<td>0.99</td>
<td>-0.37</td>
<td>1.05</td>
<td>-0.16</td>
<td>0.66</td>
<td>-0.44</td>
</tr>
<tr>
<td>PPC</td>
<td>-0.58</td>
<td>1.17</td>
<td>-0.44</td>
<td>1.35</td>
<td>-0.31</td>
<td>1.15</td>
<td>-0.42</td>
</tr>
<tr>
<td>EP</td>
<td>0.16</td>
<td>0.80</td>
<td>0.23</td>
<td>0.63</td>
<td>0.30</td>
<td>0.75</td>
<td>0.34</td>
</tr>
</tbody>
</table>

**Note:** Independent Variables:  
1. **Cardinal Science** -- A group of students who were required to undertake more than one year of university physics. In any following presentation of data, they will be labelled:  
   - CS-I -- Cardinal Science -- one year of high-school physics  
   - CS-II -- Cardinal Science -- two years of high-school physics  
2. **Required Science** -- The group of students who were not required to undertake more than one year of university physics. Its designation will be:  
   - RS-I -- Required Science -- one year of high-school physics  
   - RS-II -- Required Science -- two years of high-school physics
TABLE III (continued)

Note: (continued)

(3) Undecided -- The category of students who indicated that they were undecided as to vocational goal. Its designation will be:
   U-1 -- Undecided -- one year of high-school physics
   U-2 -- Undecided -- two years of high-school physics

Dependent Variables:

Cognitive: (1) Knowledge Pre-Test -- This test was given to the subjects to help the instructor determine a student's subject matter preparation for the course Physics 110. In any following presentation of data it will be labelled KPT. (2) Course Examinations -- The four examinations administered during the Physics 110 course. These will be designated:
   Mid-term I -- MT-1
   Xmas -- XM
   Mid-term II -- MT-2
   Terminal Examination -- TE

Attitudinal -- Measures determined from the instrument designed and administered by G. Page. Their designations will be as follows:
   Physics -- Ph
   Problem Solving -- PS
   Natural Phenomena -- NP
   Intellectual Excitement -- IE
   My Previous Physics Instructor -- PPI
   My Previous Physics Course -- PPC
   My Expectations of Physics 110 -- EP

Antecedent Measures -- These variables were entry skills, academic ability, and student background knowledge. These will have the following designations:
   The Cooperative Academic Ability Test -- CAAT
   The Verbal Component of CAAT -- VC
   The Quantitative Component of CAAT -- QC
   High-school Achievement in Physics -- HSPh
   High-school Achievement in Chemistry -- HSC
   High-school Achievement in Mathematics -- HSM
   High-school Grade Average -- HSGA
4.2 Analysis of the Data

4.2.1 Multivariate Analysis of Variance

The specific question to which the multivariate analysis of variance is directed, was:

Are there statistically significant differences between vocation-oriented groups on the selected criterion variables taken as a whole.

The relevant statistical null hypothesis tested was:

The population centroids of the different vocation-oriented groups will not differ significantly -- designated $H_2$.

A test for the equality of group dispersions $H_1$ -- was first performed to test this underlying assumption of the Multivariate Analysis of Variance procedure.

The relevant statistical hypothesis tested was:

The population dispersions of the different vocation-oriented groups will not differ significantly-designated $H_1$.

Table IV shows a summary of the MANOVA analysis.
TABLE IV
MULTIVARIATE ANALYSIS OF VARIANCE - RESULTS

<table>
<thead>
<tr>
<th>Null Hypothesis</th>
<th>F-Value</th>
<th>df₁</th>
<th>df₂</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>$H_1 = M = 5388.40$</td>
<td>0.27</td>
<td>16555.00</td>
<td>493913.75</td>
<td>p &gt; 0.05</td>
</tr>
<tr>
<td>$H_2 = \Lambda = 0.518$</td>
<td>2.28</td>
<td>110</td>
<td>1744</td>
<td>p &lt; 0.001</td>
</tr>
</tbody>
</table>

Since the test for $H_1$ was not significant at the 0.05 level of confidence, it seemed reasonable to assume that the underlying assumption was met, and therefore the test for $H_2$ is valid.

The test for $H_2$ is based on Wilk's Lambda value and for the six groups, a value of 0.518 was obtained. In testing the significance of this Lambda value, the F approximation developed by Rao\(^1\) was used. This produced an F-value of 2.28 which was significant beyond the 0.001 level of confidence. The null hypothesis was therefore rejected. This analysis showed that there was a significant difference between group centroids on the dependent variables taken all at a time.

In order to examine the nature of the group differences in terms of the dependent variables, the multivariate analysis of variance was followed by a discriminant analysis of the data shown in Table III. Since a discriminant analysis produces discriminant functions, or uncorrelated linear combinations of the original variables, interpretation of the nature of group differences is enhanced.

4.3 Discriminant Analysis

The discriminant analysis dealt with the question: "Along what (possibly psychologically meaningful) dimensions do these groups differ?" The hypothesis tested was: "If significant differences between population centroids exist, statistically significant discriminant functions can be found to differentiate between the different vocation-oriented groups."

4.3.1 Results

The results of the analysis are presented in Tables V, VI, and VII.

TABLE V

<table>
<thead>
<tr>
<th>Latent roots (Eigenvalues)</th>
<th>Percent of Trace</th>
<th>Chi-Square Value</th>
<th>Degree of Freedom</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>I 0.5633</td>
<td>72.07</td>
<td>164.44</td>
<td>26</td>
<td>0.00</td>
</tr>
<tr>
<td>II 0.1042</td>
<td>13.51</td>
<td>36.93</td>
<td>24</td>
<td>0.05</td>
</tr>
</tbody>
</table>

The first two roots reported were the only two roots that showed significant Chi-square values at or beyond the 0.05 level of confidence. The 'total discriminatory power' was 85.58 percent of the discriminant

---

TABLE VI
SCALED VECTORS FOR EACH DEPENDENT VARIABLE ON THE DISCRIMINANT FUNCTIONS

<table>
<thead>
<tr>
<th>Variables</th>
<th>Scaled Vectors</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Function I</td>
</tr>
<tr>
<td>A</td>
<td></td>
</tr>
<tr>
<td>ANTECEDENT</td>
<td>CAAT</td>
</tr>
<tr>
<td></td>
<td>VC</td>
</tr>
<tr>
<td></td>
<td>QC</td>
</tr>
<tr>
<td></td>
<td>HSPh</td>
</tr>
<tr>
<td></td>
<td>HSC</td>
</tr>
<tr>
<td></td>
<td>HSM</td>
</tr>
<tr>
<td></td>
<td>HSGA</td>
</tr>
<tr>
<td>C</td>
<td>KPT</td>
</tr>
<tr>
<td>COGNITIVE</td>
<td>MT-I</td>
</tr>
<tr>
<td></td>
<td>XM</td>
</tr>
<tr>
<td></td>
<td>MT-II</td>
</tr>
<tr>
<td></td>
<td>TE</td>
</tr>
<tr>
<td>AFFECTIVE</td>
<td>Ph</td>
</tr>
<tr>
<td></td>
<td>PS</td>
</tr>
<tr>
<td></td>
<td>NP</td>
</tr>
<tr>
<td></td>
<td>IE</td>
</tr>
<tr>
<td></td>
<td>PPJ</td>
</tr>
<tr>
<td></td>
<td>PPC</td>
</tr>
<tr>
<td></td>
<td>EP</td>
</tr>
</tbody>
</table>
space. Thus 85.58 percent of the variability in the discriminant space is relevant to group differentiation.

TABLE VII

GROUP CENTROIDS ON DISCRIMINANT FUNCTIONS I AND II

<table>
<thead>
<tr>
<th>Groups</th>
<th>Discriminant Function I</th>
<th>Discriminant Function II</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CS-1</td>
<td>4.46</td>
<td>1.59</td>
</tr>
<tr>
<td>CS-2</td>
<td>5.50</td>
<td>1.46</td>
</tr>
<tr>
<td>RS-1</td>
<td>2.85</td>
<td>1.32</td>
</tr>
<tr>
<td>RS-2</td>
<td>5.03</td>
<td>1.17</td>
</tr>
<tr>
<td>U-1</td>
<td>3.32</td>
<td>1.63</td>
</tr>
<tr>
<td>U-2</td>
<td>5.10</td>
<td>1.64</td>
</tr>
</tbody>
</table>

The Scaled vectors for each dependent variable on the two significant discriminant functions are shown in Table VI. The highest positive scaled weights on the first discriminant function are those for variables VC (17.54), QC (22.74) and KPT (22.91). The largest negative weights were, CAAT (-34.55), HSPh (-7.84) and HSGA (-7.57). The negative weights for HSPh and HSGA are small enough -- less than one quarter of CAAT -- to be discarded in the interpretation of the discriminant function.

The second discriminant function showed much the same pattern of scaled weights. The largest positive scaled weights are those for
QC (27.17) and VC (31.78). It is interesting to note that KPT is replaced by TE (11.15). However, the weight for TE is less than one-half of the weights for VC and QC, and so does not play a practical role in the interpretation of the second discriminant function. CAAT (-34.55) has a high negative scaled weight and was the only dependent variable considered in the interpretation of the function.

Figure 1 shows the group centroids plotted in the discriminant space.

The figure shows a distinct separation between the groups CS-1, RS-1, U-1 and the groups CS-2, RS-2 and U-2 on the first discriminant function. A smaller, but significant, separation can be seen on the second discriminant function between the groups RS-1, RS-2 and the other four groups, namely CS-1, CS-2, U-1 and U-2.

4.4 Interpretation of Results

4.4.1 Variables Contributing to Group Separation

To determine the relative extent to which each dependent variable (CAAT, KPT, etc.) contributed to the overall group separation on a significant discriminant function, the scale factor must be removed. The adjustment is made by multiplying the elements of each normalized weight by the square root of the corresponding diagonal elements of the W matrix, i.e. the sum of the squared deviations from the group means. These scaled values were shown in Table VI.

Although the scaled weights serve as an index for deciding which variables are important in the over-all separation, answers are
Figure 1  Group Centroids in Discriminant Space
not readily apparent as to the underlying psychological meaning of the group separation. Rather than attach an arbitrary label to the discriminant function, a more systematic approach was undertaken. The method suggested by Rulon [1952] and used by Cooley [1958], was used in the present study.

In the tables that follow a (+x) indicated that the group mean was above the grand mean and a (-x), below the grand mean. In the column 'v' is the corresponding element of the normalized latent vector. Column 'xv' contains the contribution of that variable to the group score. The group score (centroid) itself is at the top of the table. Those variables contributing directly to a group's centroid displacement are listed in order, followed by those which modified the shift away from the centre of the discriminant, or the overall mean.

A detailed examination of Tables VIII to XIII shows:

TABLE VIII
GROUP CS-1: FUNCTION I

\[ d_{11} = 3.46 \]

<table>
<thead>
<tr>
<th>Variable</th>
<th>X</th>
<th>V</th>
<th>XV</th>
</tr>
</thead>
<tbody>
<tr>
<td>VC</td>
<td>1.27</td>
<td>0.12</td>
<td>0.0324</td>
</tr>
<tr>
<td>KPT</td>
<td>-1.51</td>
<td>0.29</td>
<td>-0.4379*</td>
</tr>
<tr>
<td>CAAT</td>
<td>1.17</td>
<td>-0.16</td>
<td>-0.0702</td>
</tr>
<tr>
<td>QC</td>
<td>-0.07</td>
<td>0.20</td>
<td>-0.0140</td>
</tr>
</tbody>
</table>


### TABLE IX

**GROUP CS-2: FUNCTION I**

\[ d_{12} = 5.50 \]

<table>
<thead>
<tr>
<th>Variable</th>
<th>X</th>
<th>V</th>
<th>XV</th>
</tr>
</thead>
<tbody>
<tr>
<td>KPT</td>
<td>3.65</td>
<td>0.29</td>
<td>1.0595*</td>
</tr>
<tr>
<td>QC</td>
<td>1.58</td>
<td>0.20</td>
<td>0.3160</td>
</tr>
<tr>
<td>VC</td>
<td>0.27</td>
<td>0.12</td>
<td>0.0324</td>
</tr>
<tr>
<td>CAAT</td>
<td>1.88</td>
<td>-0.16</td>
<td>-0.3008</td>
</tr>
</tbody>
</table>

### TABLE X

**GROUP RS-1: FUNCTION I**

\[ d_{13} = 2.85 \]

<table>
<thead>
<tr>
<th>Variable</th>
<th>X</th>
<th>V</th>
<th>XV</th>
</tr>
</thead>
<tbody>
<tr>
<td>CAAT</td>
<td>-2.82</td>
<td>-0.16</td>
<td>0.4512</td>
</tr>
<tr>
<td>KPT</td>
<td>-2.38</td>
<td>0.29</td>
<td>-0.6902*</td>
</tr>
<tr>
<td>VC</td>
<td>-0.31</td>
<td>0.12</td>
<td>-0.0302</td>
</tr>
</tbody>
</table>
TABLE XI

GROUP RS-2: FUNCTION I

\[ d_{14} = 5.03 \]

<table>
<thead>
<tr>
<th>Variable</th>
<th>X</th>
<th>V</th>
<th>XV</th>
</tr>
</thead>
<tbody>
<tr>
<td>KPT</td>
<td>1.85</td>
<td>0.29</td>
<td>0.5365*</td>
</tr>
<tr>
<td>QC</td>
<td>0.90</td>
<td>0.20</td>
<td>0.1800</td>
</tr>
<tr>
<td>VC</td>
<td>0.73</td>
<td>0.12</td>
<td>0.0876</td>
</tr>
<tr>
<td>CAAT</td>
<td>2.18</td>
<td>-1.16</td>
<td>-0.305</td>
</tr>
</tbody>
</table>

TABLE XII

GROUP U-1: FUNCTION I

\[ d_{15} = 3.32 \]

<table>
<thead>
<tr>
<th>Variables</th>
<th>X</th>
<th>V</th>
<th>XV</th>
</tr>
</thead>
<tbody>
<tr>
<td>CAAT</td>
<td>-3.13</td>
<td>-0.16</td>
<td>0.5008</td>
</tr>
<tr>
<td>VC</td>
<td>0.73</td>
<td>0.12</td>
<td>0.0876</td>
</tr>
<tr>
<td>KPT</td>
<td>-2.08</td>
<td>0.29</td>
<td>-0.6032*</td>
</tr>
<tr>
<td>QC</td>
<td>-1.02</td>
<td>0.20</td>
<td>-0.2040</td>
</tr>
</tbody>
</table>

*Variable contributing most to group centroid modification.
TABLE XII

GROUP U-2: FUNCTION I

\[ d_{16} = 5.10 \]

| Variables | X  | V  | XV *
|-----------|----|----|-----
| KPT       | 2.21 | 0.29 | 0.6409
| QC        | 1.32 | 0.20 | 0.2640
| VC        | -0.52 | 0.12 | -0.0624
| CAAT      | +0.20 | -0.16 | -0.0320

1. **Groups CS-1, RS-1 and U-1.** Since the high (negative) weighted variates out-weigh the high (positive) weighted variates, the group centroid was 'pulled back' towards the overall mean by the negatively weighted variables. For each group the dependent variable KPT contributed most to the modification of the group centroid position.

2. **Groups CS-2, RS-2 and U-2.** The high (positive) weighted variates out-weigh the high (negative) weighted variates, therefore the group centroid was moved away from the overall mean -- or, the group centroid was 'pulled away' from the overall mean. The dependent variable KPT contributed most, for each group, to the modification of the centroid position.

*Variable contributing most to group centroid modification.*
A similar analysis and interpretation of the second discriminant function was not necessary, as the most heavily weighted dependent variables -- CAAT, VC and QC -- gave a fairly clear picture of the nature of the group separation in terms of academic ability.

4.5 Summary of Results

The acceptance of the null hypothesis $H_0$: "The population dispersions of the different vocationally-oriented groups will not differ." Made the test of $H_1$: "The population centroids of the different vocation-oriented groups will not differ significantly," tenable. The null hypothesis $H_2$ was rejected and a discriminant analysis was performed on the data to determine the nature of the group differences. Two significant discriminant functions were found to account for 85.58 percent of the variability in the discriminant space relevant to group separation. The scaled vectors (or weights) showed that on the first function the dependent variables VC, QC, and KPT and CAAT contributed most to the group separation. Further analysis of the variables on the first discriminant function showed that the variable KPT contributed most to the separation of the groups along this function.

The same pattern of variables and weights occurred on the second discriminant function, but with the omission of the dependent variable KPT.
CHAPTER V

CONCLUSIONS

5.1 The Problem

Classroom experience with first-year courses at the college level sometimes raises the question of whether or not special provision should be made for different groups of students taking a first year course. Ginzberg [1951]¹ pointed out that education should contribute to the specific aims of students, such as an effective resolution of the problem of vocational choice. Facilitating vocational choice is an urgent matter at the college level, because first-year college courses often serve as choice-points at which final decisions about a vocation are made. The importance of assisting students in making a vocational choice has been documented by Havinghurst [1953]² and Super [1963].³

The general problem of the study was to determine the nature of the differences between various vocation-oriented groups of students taking a first-year college course, with a view to accommodating these differences, if possible, in the classroom. The differences were examined in terms of a number of selected dependent variables deemed


important to the instructor of the course, for instructional purposes.

More specifically, the problem of identifying and describing variables which could serve to discriminate between groups defined, a priori, on the basis of vocational choice, was undertaken. Two particular questions, related to the broader problem, were dealt with. These were:

1. Are there statistically significant differences between different vocation-choice groups on the selected criterion variables, taken as a whole?
2. Along what (possibly psychologically meaningful) dimensions do these groups differ?

The conclusions reached are dealt with in this chapter. Recommendations for further study will be suggested in the last section of the chapter.

5.2 Conclusions

5.2.1 Group Differences

The results show that the nineteen dependent variables, taken as a whole, had the power to discriminate between certain vocation-oriented groups (see Chapter IV, Section 4.1.1). These differences, however, though statistically significant, do not necessarily imply any practical significance. A discriminant analysis was carried out to determine the nature of the group differences.
5.2.2 Discriminant Analysis

Discriminant analysis was performed to determine the relative extent to which each of the original dependent variables contributed to group separation. Two discriminant functions proved to be statistically significant in accounting for group differences.

Scaled weights were used as indices for deciding which of the variables contributed most to group centroid separation. By examining the relative importance of each variable in this way, the discriminant functions were interpreted as psychological dimensions of group differences. Examination of these dimensions suggested important differences between the groups that could be useful in planning classroom instruction.

First Discriminant Function

A study of the first discriminant function (Figure 1) showed that those students with two years of high-school physics were clearly separated from those with just one year of high-school physics.

The dependent variables contributing most to the separation of the vocation-oriented groups:

Cardinal Science -- one year of high-school physics (CS-1)
Required Science -- one year of high-school physics (RS-1)
Undecided -- one year of high-school physics (U-1)

from the groups:

Cardinal Science -- two years of high-school physics (CS-2)
Required Science -- two years of high-school physics (RS-2)
Undecided -- two years of high-school physics (U-2)

along the first dimension were the verbal component (VC) and quantitative component (QC) of the Cooperative Academic Ability Test (CAAT), Knowledge Pre-Test (KPT) and the total CAAT scores.

The Cooperative Academic Ability Test (CAAT) is designed to yield a reliable and valid estimate of academic ability. Thus it is reasonable to conclude that the vocation-oriented groups differed, in part, on this attribute.

The variable KPT (Knowledge Pre-Test) also had a significant weight on the first function. This suggests that the amount of experience a student has in high-school physics also served to distinguish between the groups. A more detailed 'post facto' analysis given in the preceeding chapter (Section 4.4) substantiates this contention. In this analysis the variable KPT contributed most to the translation of the group centroids along first dimension, relative to the overall group discriminant mean.

The Knowledge Pre-Test was administered to the students before the course (Physics 110) started. It was designed to provide the instructor with information relating to the skills and knowledge students had prior to the course. Thus these results tend to support the claim that what separates the vocation-oriented groups is not only academic ability, but also prior high-school experience in a subject area.
Second Discriminant Function

The plot of the group centroids (Figure 1) shows a separation of the groups RS-1, RS-2 from the other groups -- CS-1, CS-2, U-1, U-2. The variables contributing most to this separation were much the same as those for the first function. The major difference being, that only the variables VC, QC and CAAT were weighted heavily, and no other variable played a significant role in group separation. Evidently, certain vocation-oriented groups can be distinguished on the basis of academic ability alone.

The overall conclusion that is suggested, is that only the Required Science (RS) groups can be clearly distinguished from the other vocation-oriented groups. The major distinction being that the Required Science (RS) groups do not appear to be as capable, academically, as the rest. Years of schooling in a subject area is an important discriminating factor for instructional purposes, but this factor does not differentiate between the various vocation-oriented groups.

An implication of the study is that the treatment of students in a freshman physics course should be considered on the basis of:

1. The number of years of high-school physics experience and
2. Whether or not students are simply taking the course as a prerequisite to further study.

5.3 Recommendations for Further Study

In view of the results obtained, a number of recommendations for further study in the area of schooling in relation to vocational choice follow:
1. What sort of instruction should the RS types of students receive?

2. Why are the affective factors not important in distinguishing between vocation-oriented groups?

3. Since the group of undecided students, those without a specific vocational goal in mind, did not differ significantly from some vocationally oriented students, it would be of interest to examine how a career planning programme could affect the achievement of these undecided students.

4. Would vocationally committed students obtain any benefit from a career planning programme through the development of a wider view-point and experience, in career planning?

In summary the author would like to refer back to a study quoted in Chapter II, by Mallinson [1968], as this present study showed a remarkable degree of agreement with one of his conclusions, namely:

The two most significant factors related to overall achievement in College were the student's IQ and his belief that his parents thought education was important. With respect to the election of, and achievement in, Science courses, an influential factor, in addition to the two above, was the number of science courses taken in high-school.  

---

BIBLIOGRAPHY


ALLPORT, G.W. The Use of Personal Documents in Psychological Sciences. New York, Social Science Research Council, 1942.


CRONBACH, LEE, J. "Evaluation for Course Improvement," Teacher College Record 64. 1963.


EDUCATIONAL TESTING SERVICE. Cooperative Test Division. California, 1967.


HAVINGHURST, R.J. Human Development & Education. New York, Longmans Green, 1953.


APPENDICES
PHYSICS INFORMATION SHEET

Please Print

Name ___________________________ Surname ___________________________ Given Names ___________________________ Reg. No. ___________________________

School Last Attended:
Secondary ___________________________
College ___________________________

Name of School ___________________________ Location ___________________________
Name of College ___________________________ Location ___________________________

High School Graduating Average ___________________________ %

Math and Science Course Completed in secondary School (circle appropriate numbers and indicate final mark and year completed)

<table>
<thead>
<tr>
<th>Course</th>
<th>Respective Marks</th>
<th>Year Taken</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physics</td>
<td>91,11,12</td>
<td></td>
</tr>
<tr>
<td>Chemistry</td>
<td>91,11,12</td>
<td></td>
</tr>
<tr>
<td>Biology</td>
<td>91,11,12</td>
<td></td>
</tr>
<tr>
<td>Math</td>
<td>91,11,12</td>
<td></td>
</tr>
<tr>
<td>Other (specify)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Other lab Science courses taken this year (give course numbers)

Biology____ Chemistry____ Engineering____ Other____

Professional Objective -- Check (√) one item where applicable.

__ Undecided ______ Engineering ______ Ministry
__ Agriculture ______ Forestry ______ Music
__ Architecture ______ Geology ______ Pharmacy
__ Armed Services ______ Home Economics ______ Physics
__ Bio-Sciences ______ Journalism ______ Physical Education
__ Business (Comm.) ______ Library ______ Social Work
__ Chemistry ______ Law ______ Teaching
__ Civil Service ______ Medicine ______ Other__________
__ Dentistry ______ Rehab. Medicine ______
APPENDIX B

Semantic-Differential Instrument
PHYSICS EDUCATION EVALUATION PROJECT

The purpose of this study is to measure your perception of certain concepts related to physics and physics courses, by having you judge these concepts against a series of descriptive scales. You are asked to make your judgments on the basis of what these concepts mean to you. THIS IS NOT A TEST, as there are no right or wrong answers, and your responses will in no way influence your grades in this course.

You will find the concepts to be judged in bold face letters. For example,

REGISTRATION AT U.B.C.

Below this headline concept are a series of descriptive scales against which you will judge the concept. An example of a descriptive scale is

chaotic == == == == == == == == ordered

If you feel that the headline concept is very closely related to one end of the scale, you should respond:

chaotic == == == == == == == == ordered

OR

chaotic == == == == == == == == ordered

If you feel that the headline concept is quite closely related to one or the other end of the scale (but not extremely), you should respond:

chaotic == == == == == == == == ordered

OR

chaotic == == == == == == == == ordered

If the headline concept seems only slightly related to one side as opposed to the other side (but is not really neutral), then you should respond:

chaotic == == == == == == == == ordered

OR

chaotic == == == == == == == == ordered
The direction toward which you respond, of course, depends upon which of the two ends of the scale seem most characteristic of the thing you are judging.

If you consider the object to be neutral on the scale, both sides of the scale equally associated with the object, or if the scale is completely irrelevant, unrelated to the object, then you should respond in the middle space:

chaotic: == == == == == == == ordered

IMPORTANT: (1) Be sure to respond to every scale for every concept.

(2) Do not make more than one response on a given scale.

(3) Respond using the pencil provided.

Work at a fairly rapid pace. Do not puzzle over individual items. Give your first impressions, the immediate "feelings" about the items. On the other hand, please do not be careless, because it is your true impressions that are important.

Below is part of a sample page for you to fill in for practice. Do not spend more than a few seconds marking each scale. Your first idea is what is wanted. You can work faster if you do the following:

First, form a picture in your mind of the headline concept (in this case "University Learning").

Then, read each scale and make your responses very rapidly.

--------------------------------------------------------

UNIVERSITY LEARNING

valuable == == == == == == == worthless
difficult == == == == == == == easy
beneficial for society == == == == == == harmful for society
mysterious == == == == == == understandable
dead == == == == == == alive

PLEASE DO NOT TURN THE PAGE UNTIL TOLD TO DO SO.

THANK YOU.
DIRECTIONS: Make your mark as long as the pair of lines, and completely fill in the area between the pair of lines. If you change your mind, erase your first mark COMPLETELY.
DIRECTIONS: Make your mark as long as the pair of lines, and completely fill in the area between the pair of lines. If you change your mind, erase your first mark COMPLETELY.

NATURAL PHENOMENA

- Important
- Not applicable
- Beneficial for society
- Passive
- Never intellectually exciting
- Mysterious
- Valuable
- Efficient
- Not needed by society
- Challenging
- Good
- Miraculous
- Dead
- Intuitive
- Weak
- Never fun
- Nice
- Moving
- Should be guided by society
- Rewarding
- Difficult
- Interesting
- Opportunity for initiative
- Tricky
- Discouraging
- Never dull
- Beautiful
- Slow
- Clarifies
- Wide
- Meaningless
- Unnecessary

INTELLECTUAL EXCITEMENT

- Important
- Not applicable
- Beneficial for society
- Passive
- Never intellectually exciting
- Mysterious
- Valuable
- Efficient
- Not needed by society
- Challenging
- Good
- Miraculous
- Dead
- Intuitive
- Weak
- Never fun
- Nice
- Moving
- Should be guided by society
- Rewarding
- Difficult
- Interesting
- Opportunity for initiative
- Tricky
- Discouraging
- Never dull
- Beautiful
- Slow
- Clarifies
- Wide
- Meaningless
- Unnecessary
DIRECTIONS: Make your mark as long as the pair of lines, and completely fill in the area between the pair of lines. If you change your mind, erase your first mark COMPLETELY.

MY PREVIOUS PHYSICS COURSE

|-----------|-------------|----------------|------------------------|---------|------------------------------|-----------------------------|------------|---------|------|----------|-----------------------|------------|-----|-----------|-----|----------|------|----------|------|--------|--------------------------|-----------|----------|-----------|-----------------------------|------|-----------|----------|-----------|------|---------|--------|-----------|------|----------|--------|

MY PREVIOUS PHYSICS INSTRUCTOR

DIRECTIONS: Make your mark as long as the pair of lines, and completely fill in the area between the pair of lines. If you change your mind, erase your first mark COMPLETELY.

MY EXPECTATIONS TOWARD PHYSICS 110

important ====== unimportant
not applicable ====== applicable
beneficial for society ====== harmful for society
passive ====== active
never intellectually exciting ====== sometimes intellectually exciting
oriented toward principles ====== oriented toward facts
mysterious ====== understandable
valuable ====== worthless
small ====== large
efficient ====== inefficient
not needed by society ====== needed by society
challenging ====== not challenging
good ====== bad
miraculous ====== rational
dead ====== alive
intuitive ====== theoretical
weak ====== strong
never fun ====== always fun
nice ====== awful
moving ====== still
should be guided by society ====== should not be guided by society
rewarding ====== unrewarding
difficult ====== easy
interesting ====== not interesting
opportunity for initiative ====== no opportunity for initiative
tricky ====== straightforward
discouraging ====== encouraging
never dull ====== always dull
beautiful ====== ugly
slow ====== fast
clarifies ====== complicates
wide ====== narrow
meaningless ====== meaningful
unnecessary ====== necessary
APPENDIX C

Knowledge Pre-Test
Instructions

This is not a course examination. The results will not count toward your grade. This test is part of a national study on physics teaching, and your cooperation in completing it will help improve physics instruction in this and similar introductory courses.

You will have forty (40) minutes to complete the 37 questions of this test. Each question has four or five choices. Choose one of these, and mark the proper space on the answer sheet with a lead pencil. Note that the question numbers on the answer sheet run horizontally across the page.

If after you have chosen one of the given alternatives, you feel you would rather have given an answer other than those listed, write your answer on the back of the yellow sheet (last page of this booklet).

If a question seems too difficult, make the most careful guess you can, rather than waste time over it. It is important that you answer all questions.

EXAMPLE

1. The president of the University of British Columbia is
   1. Tom Jones
   2. Hugh Hefner
   3. Ronald Regan
   4. Walter Gage
   5. W.A.C. Bennett

   1.  2  3  4  5
1. Two sacks of identical marbles are hung one meter apart. Which of the following conditions would approximately double the gravitational force that one sack of marbles exerts on the other sack?
   1. Move them closer, to one-half the separation.
   2. Move them further apart, to twice the separation.
   3. Move them further apart, to four times the separation.
   4. Double the number of marbles in one sack.
   5. Double the number of marbles in both sacks.

   If you would rather answer in a different way, please do so on the back of the yellow sheet.

2. Consider the following:
   A. a wire loop surrounding a wire with a steady current.
   B. a magnet dropping through a wire loop.
   C. a stationary magnet at the center of a wire loop.
   In which of the above is a current produced in the wire loop?
   1. A only
   2. B only
   3. C only
   4. A and C only
   5. B and C only

   If you would rather answer in a different way, please do so on the back of the yellow sheet.

3. Two spheres, one of mass 5 kilograms and the other of mass 10 kilograms, are dropped at the same time from the top of a tower (neglect air friction). When they are 1 meter above the ground, the two spheres have the same
   1. momentum.
   2. kinetic energy.
   3. potential energy.
   4. total mechanical energy.
   5. acceleration.

   If you would rather answer in a different way, please do so on the back of the yellow sheet..
4. A beam of electrons is directed between two charged plates as indicated in the diagram at the right. Once the beam is between the plates it will

1. curve in direction A.
2. curve in direction B.
3. curve in direction C.
4. curve in direction D.
5. continue in a straight line.

If you would rather answer in a different way, please do so on the back of the yellow sheet.

Questions 5 and 6 refer to the following situation.

During a maneuver in space flight, a free-floating astronaut pushes a free-floating instrument package. The mass of the astronaut is greater than that of the instrument package.

5. The force exerted by the astronaut on the instrument package is:

1. equal to the force exerted by the package on the astronaut.
2. greater than the force exerted by the package on the astronaut.
3. less than the force exerted by the package on the astronaut.
4. equal to zero.
5. greater than, less than, or equal to the force exerted by the package on the astronaut; one cannot tell with the information given here.

If you would rather answer in a different way, please do so on the back of the yellow sheet.

6. During the push by the astronaut on the package

1. the magnitude of the acceleration of the astronaut is greater than that of the instrument package.
2. the magnitude of the acceleration of the astronaut is smaller than that of the instrument package.
3. neither astronaut nor instrument package are accelerated.
4. the accelerations of each are equal in magnitude but opposite in direction.
5. the accelerations of each are equal in magnitude and in the same direction.

If you would rather answer in a different way, please do so on the back of the yellow sheet.
7. Gamma rays are
   1. high frequency electromagnetic radiation.
   2. identical to electrons.
   3. like electrons, but with a positive charge.
   4. nuclei of the element helium.
   5. nuclei of the element hydrogen.

If you would rather answer in a different way, please do so on the back of the yellow sheet.

8. Which of the following is a vector quantity?
   1. Work
   2. Kinetic energy
   3. Force
   4. Potential energy
   5. Power

If you would rather answer in a different way, please do so on the back of the yellow sheet.

9. Two spheres, A and B, are 4 meters apart. A charge of 2 micro coulombs is distributed over sphere A and a charge of 1 micro coulomb is distributed over sphere B. (See sketch.)

How does the magnitude of the force exerted by A on B compare with the magnitude of the force exerted by B on A?
   1. The force on A is 4 times the force on B.
   2. The force on A is 2 times the force on B.
   3. The force on A is the same as the force on B.
   4. The force on A is \( \frac{1}{2} \) the force on B.
   5. The force on A is \( \frac{1}{4} \) the force on B.

If you would rather answer in a different way, please do so on the back of the yellow sheet.
10. Someone lifts a bowling ball from the floor and places it on a rack. If you know the weight of the ball, what else must you know in order to calculate the work he does on the ball?

1. nothing else.
2. how much force it takes to lift it.
3. how fast it was lifted.
4. how far it was lifted.
5. how long it took to lift it.

If you would rather answer in a different way, please do so on the back of the yellow sheet.

11. When two waves pass the same point at the same time, the waves at this point always

1. cancel out
2. reflect off each other
3. reinforce each other
4. hinder each others progress
5. superimpose

If you would rather answer in a different way, please do so on the back of the yellow sheet.

THE REMAINING QUESTIONS ONLY PROVIDE 4 ALTERNATIVES WHEREAS THE ANSWER SHEET STILL PROVIDES FOR 5 ALTERNATIVES. RESPONSE CATEGORY 5 ON THE ANSWER SHEET SHOULD BE IGNORED FOR THESE QUESTIONS.

12. Scientists on the imaginary planet Q have defined a unit of length, the "lar", to be the distance between two mountain peaks on the surface of the planet. The unit of time on the planet Q is called the "tik", and is defined as the average interval between pulsebeats of the king.

What units would express acceleration on planet Q if acceleration were defined as it is on earth?

1. lar/tik
2. \( \frac{1}{2} \text{ lar tik}^2 \)
3. tik/lar
4. lar/tik^2

If you would rather answer in a different way, please do so on the back of the yellow sheet.
13. An oxygen atom consists of:
1. a nucleus (neutrons and electrons) surrounded by a cloud of protons.
2. a nucleus (protons and electrons) surrounded by a cloud of neutrons.
3. a nucleus (neutrons) surrounded by a cloud of protons and electrons.
4. a nucleus (protons and neutrons) surrounded by a cloud of electrons.

If you would rather answer in a different way, please do so on the back of the yellow sheet.

14. A body of mass m moving from rest at constant acceleration a reaches a final velocity \( v_f \) in time t. The kinetic energy at final velocity is
1. \( mv_f \)
2. \( ma \)
3. \( \frac{1}{2}mv_f^2 \)
4. at

If you would rather answer in a different way, please do so on the back of the yellow sheet.

15. An object at rest may have a non-zero amount of
1. momentum
2. kinetic energy
3. potential energy
4. velocity

If you would rather answer in a different way, please do so on the back of the yellow sheet.

16. If an object of mass m is at rest at a distance h above ground, and the acceleration of gravity is g, the potential energy of the object is
1. \( mg \)
2. \( mgh \)
3. \( \frac{1}{2}mgh^2 \)
4. \( mggh \)

If you would rather answer in a different way, please do so on the back of the yellow sheet.
17. Given F and F' are the foci of the lens, the image of object 0 is most correctly represented by

1. 1
2. 2
3. 3
4. 4

If you would rather answer in a different way, please do so on the back of the yellow sheet.

18. Two planetary bodies whose centres are separated by a distance r are attracted to each other by a gravitational force which is proportional to:

1. r
2. r^2
3. 1/r
4. 1/r^2

If you would rather answer in a different way, please do so on the back of the yellow sheet.

19. When the speed of a car is doubled, the car's

1. kinetic energy is doubled
2. potential energy is doubled
3. momentum is doubled
4. inertia is doubled

If you would rather answer in a different way, please do so on the back of the yellow sheet.

20. A point charge +Q_1 exerts an electrostatic force F on point charge +Q_2 3 centimeters away. If the charges are placed 6 centimeters apart, the magnitude of the electrostatic force +Q_1 exerts on +Q_2 will be

1. 4F
2. 2F
3. F/2
4. F/4

If you would rather answer in a different way, please do so on the back of the yellow sheet.
21. Work equals
1. force x displacement
2. energy ÷ time
3. mass x velocity
4. force x time

If you would rather answer in a different way, please do so on the back of the yellow sheet.

22. ALL EXCEPT ONE of the following particles can be accelerated by an electric or magnetic field. Which one is the exception?
1. electron
2. proton
3. neutron
4. alpha particle

If you would rather answer in a different way, please do so on the back of the yellow sheet.

Questions 23 and 24 refer to the following diagram.

23. The graph represents the speed of a car travelling along a straight road. The maximum acceleration occurs at the time
1. 1
2. 2
3. 3
4. 4

If you would rather answer in a different way, please do so on the back of the yellow sheet.

24. The speed is greatest at the time corresponding to point
1. 1
2. 2
3. 3
4. 4

If you would rather answer in a different way, please do so on the back of the yellow sheet.
25. "There is an electric field at this point" means:
1. There is an electric charge at this point.
2. A charged object at this point would experience a force.
3. The charge at this point is different from the charges in neighbouring points.
4. Electric charges (a current) are moving through this point.

If you would rather answer in a different way, please do so on the back of the yellow sheet.

26. A flower pot starting from rest is dropped from a window sill, and strikes the ground with velocity \( v_f \) after a time \( t \) in free fall (acceleration due to gravity \( g \)). Neglecting air resistance, the distance \( d \) of the window sill from the ground could be found by using the equation
1. \( d = v_f t \)
2. \( d = v_f t + \frac{1}{2} gt^2 \)
3. \( d = \frac{1}{2} gt^2 \)
4. \( d = \frac{v_f^2}{g} \)

If you would rather answer in a different way, please do so on the back of the yellow sheet.

27. A communications satellite of mass \( m \) is in a circular orbit of radius \( r \). If its velocity is \( v \), the centripetal force it experiences is
1. \( \frac{v^2}{r} \)
2. \( mv^2/r \)
3. \( mv \)
4. \( \frac{1}{2}mv^2 \)

If you would rather answer in a different way, please do so on the back of the yellow sheet.

28. A vertical wire hidden in a wall is carrying a direct current. What piece of equipment might help you best find the location of the wire?
1. galvanometer
2. charged pith ball on a string
3. compass
4. radio receiver

If you would rather answer in a different way, please do so on the back of the yellow sheet.
35. \( y = 6x^2 - 2x + 7 \); \( \frac{dy}{dx} = \\
1. 6x-2 \\
2. 12x-2 \\
3. 6x-2+7/x \\
4. 2x^3-x^2+7x \\

36. \( \int_{0}^{x} (2x+5) \, dx = \\
1. x^2 \\
2. x^2+5x \\
3. 2 \\
4. 2x^2+5x \\

37. Vectors and scalars have the following properties: \\
1. vector: direction and magnitude \\
   scalar: direction only \\
2. vector: direction only \\
   scalar: direction and magnitude \\
3. vector: magnitude only \\
   scalar: direction and magnitude \\
4. vector: direction and magnitude \\
   scalar: magnitude only
<table>
<thead>
<tr>
<th>QUESTION NUMBER</th>
<th>ANSWER</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>
APPENDIX D

Mid-Term I Examination
PHYSICS 110 SECTION 1
MIDTERM EXAM, NOVEMBER 1969

NAME ____________________________ (Please Print)

REG. NO. ____________________________

Physics High School Background
Physics II only ______________________
Physics II and II2 ____________________
Other (Specify) ______________________

This examination consists of 7 sheets (front page included). Please make sure that you have a complete paper. For rough work, please use back of the sheets.

DO NOT FILL IN, PLEASE

Marks:

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2a</th>
<th>2b</th>
<th>2c</th>
<th>3a</th>
<th>3b</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7a</th>
<th>7b</th>
<th>TOTAL</th>
</tr>
</thead>
</table>
1. In terms of the meter-kilogram-second system, in which units do you give a centripetal acceleration?

ANSWER: ____________________________

2. Definition of force
   a) Give a definition of force, in the form of an equation.

   ANSWER: ____________________________

   b) Explain the meaning of the symbols used.

   (3)

   c) Is this definition valid outside the realm of classical physics? (Check appropriate box)

      YES [ ]      NO [ ]

      Give reason for your answer 2c)
3. Law of Conservation of Momentum
   
a) State the law of conservation of momentum. (If you state it in
   the form of an equation, explain the meaning of the symbols used)

b) Draw a sketch of an experiment demonstrating the law of conservation
   of momentum.
4. On the surface of the earth, a net force of 1 newton is required to give an object of mass 1 kg an acceleration of 1 m sec\(^{-2}\).

On the surface of the moon, the net force required to give the same object the same acceleration as above would be:

- [ ] the same
- [ ] not the same
- [ ] cannot be answered with the data provided

If you would rather answer in a different way, please do so on the back of the preceding page.

5. A truck of mass \(m_1 = 4,000\) kg with a trailer of mass \(m_2 = 2,000\) kg are moving along a level road with a constant speed of \(v_0 = 5\) m sec\(^{-1}\).

The truck then gives the truck-and-trailer combination a constant acceleration of \(a = 0.5\) m sec\(^{-2}\) during a time interval \(\tau = 20\) sec.

Which of the following data would you need to find the tension of the coupling during the time of acceleration? (Friction neglected) (You are not requested to calculate the result of this problem. It is only required to sort the data given in the way indicated below)

<table>
<thead>
<tr>
<th></th>
<th>Needed</th>
<th>Not Needed</th>
</tr>
</thead>
<tbody>
<tr>
<td>(m_1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(m_2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(v_0)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(a)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(\tau)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The speed of low-orbit satellites (i.e. radius of orbit $r$, radius of earth, $R_e$) is 8 km/sec. What speed if required for an earth satellite to maintain a circular orbit with a radius of $2R_e$?

**ANSWER:** _____________________________ (5)
In the attached copy (next page) from a newspaper report, a freely floating astronaut is shown, comparing the masses of two miniature planets by use of a double-pan balance.

Let us assume that the balance is not sensitive enough to be deflected by gravitational forces acting between any parts of the system shown (astronaut, equipment, miniature planets).

a) If the astronaut is close to a strongly gravitating planet, would this balance work?

____ YES  ____ NO

Give reasons for your answer.

b) If the astronaut were far away from any cosmic object, how could he find out (using the equipment shown) which of the miniature planets has the greater mass?

Describe his possible actions and observations in detail. If you need more space for writing, use the back of the preceding page.
MAXWELL COHEN

the technology and the romance of
grams have deflected awareness from
of this moonmark moment in the
the truth is that the advent into
of it, a new
wing this
dition and

opened to
len and
that
million
home
... of the
For
... uniting
vant sci-
ble not
three
ent to tel
eyes le

er to be
lealed
ning
the
ome-
ers
ed,
... to
... of
ary re-
and
ugh
ps

lit and

ent with
unic
eyt,

yet
space
APPENDIX E

Xmas Examination
THE UNIVERSITY OF BRITISH COLUMBIA
CHRISTMAS EXAMINATIONS - DECEMBER, 1969

PHYSICS 110
Section 1 (Tues, Wed, Fri 8:30)
(Mechanics, Electricity, and Atomic Structure)

Time: 2 hours

IMPORTANT

This examination consists of 10 pages (this page included). Before starting check that you have a complete paper. Show all your calculations, do rough work on the back of the pages.
Notice: Two choices are provided for question 9, three choices are provided for question 10.

Please give your name and registration number on both the first and second page.
1) Express, in terms of meter, kilogram, second, the unit of work

2) Give Newton's Universal Law of Gravity in the form of an equation.

3) Law of Conservation of Angular Momentum
   (a) State the law in its general form, in words:

   (b) Give, with the aid of a drawing, an example of a situation demonstrating the law.
4) Assume a researcher claims that he has detected a new form of energy (e.g. contained in the analytic transcendentiality of elephants, or whichever the seat of this assumed new kind of energy might be). In order to show that this energy actually exists (in the meaning of the word energy as used in physics), what kind of proof would the researcher have to give? Give a brief answer, not exceeding 50 words (positively only the first 50 words will be read for marking).

5) For a certain spring, a mass of 100 grams, attached to the spring, performs a simple harmonic motion of amplitude 1 cm. The period is 1 sec.

(a) What would the period be if the same mass would be oscillating with an amplitude of 2 cm?

(b) What would the period of the same system be at an amplitude of 1 cm, if a 200 gram mass was used instead of the 100 gram mass?
6) During a maneuver in space flight, a free-floating astronaut pushes a free-floating instrument package. The mass of the astronaut is greater than that of the instrument package.

The magnitude of the force exerted by the astronaut on the instrument package is

- equal to the magnitude of the force exerted by the package on the astronaut.
- greater than the magnitude of the force exerted by the package on the astronaut.
- less than the magnitude of the force exerted by the package on the astronaut.
- greater than, less than, or equal to the magnitude of the force exerted by the package on the astronaut; one cannot tell with the information given here.

If you would rather answer in a different way, please do so on the back of the preceding page.

During the push by the astronaut on the package,

- the magnitude of the acceleration of the astronaut is greater than that of the instrument package.
- the magnitude of the acceleration of the astronaut is smaller than that of the instrument package.
- neither astronaut nor instrument package are accelerated.
- the accelerations of each are equal in magnitude but opposite in direction.
- the accelerations of each are equal in magnitude and in the same direction.

If you would rather answer in a different way, please do so on the back of the preceding page.

7) The following refers to frames of reference in classical mechanics (i.e. relativity excluded)

a) The potential energy of a particle depends on the following properties of the frame of reference:

- velocity and location, ___velocity only, ___location only.

b) The kinetic energy of a particle depends on the following properties of the frame of reference:

- velocity and location, ___velocity only, ___location only.
8) The pendulum shown consists of a stick of length \( l = 0.6 \text{ m} \) of negligible mass, and a pendulum bob of mass \( m = 0.5 \text{ kg} \). In its equilibrium position, the bob is given an initial speed of \( v_0 = 5 \text{ m/sec} \).

Is this speed sufficient to make the pendulum swing through the maximum point, \( P \), on the circle? (see diagram). \( g = 9.8 \text{ m/sec}^{-2} \); friction neglected. (credit will be given only if your work is shown).

ANS: \( \underline{\text{Will reach } P} \)
\( \underline{\text{Will not reach } P} \)

You have the CHOICE between Question 9a and 9b. Read both questions before attempting one of these two.

9a) The figure represents the potential energy diagram for an atom in a molecule. The quantities \( a, b, c \) are amounts of energy (they are positive). \( W_0 = KE + U \). Express the following quantities in terms of \( a, b, \) and \( c \) when the atom is in position \( x_1 \). Do not ignore minus signs in your answer.

What is the potential energy? \( \underline{\text{[2]}} \)

What is the kinetic energy? \( \underline{\text{[2]}} \)

What is the total energy? \( \underline{\text{[2]}} \)

What is the energy of dissociation (i.e. the amount of additional energy to remove the atom from the molecule)? \( \underline{\text{[2]}} \)
You have the CHOICE between questions 9a and 9b. Read both questions before attempting one of these two.

9b) An iron block of temperature $T_1 = 20^\circ C$ is given an initial speed $v_0$ on a rough surface. Due to friction, it comes to rest after sliding for $t = 3$ seconds. At this time, the temperature of the iron block is $T_2 = 20.5^\circ C$. It takes 460 joules per kilogram to increase the temperature of iron by one degree centigrades. Which initial speed, $v_0$, did the block at least have?

(No credit for the obvious answer: "at least $v_0 = 0$")

ANS.: The initial speed of the block was at least _______ [8]
You have the CHOICE between Questions 10a, 10b, and 10c. Have a look at all the three questions before you attempt one of these.

10a) IS \( \vec{a} = \frac{\Delta \vec{v}}{\Delta t} \) (or, in its more general form, \( \vec{a} = \frac{\Delta \vec{v}}{\Delta t} \)), A LAW OF PHYSICS?

If you decide that it is a law, describe what the word "law" means in physics, and explain why \( \vec{a} = \frac{\Delta \vec{v}}{\Delta t} \) is in accordance with these characteristics.

If you decide that it is not a law, describe what the word "law" means in physics, and why \( \vec{a} = \frac{\Delta \vec{v}}{\Delta t} \) does not meet the requirements stated in your description of the concept "law".

Please draft your answer on the back of the exam sheets. The draft will not be read for marking. Then give your final answer briefly (not more than 150 words, \( \approx 8 \) sentences) on this page.

POSITIVELY ONLY THE FIRST 150 WORDS ON THIS PAGE WILL BE READ

My final brief answer is:

Therefore, in my opinion, \( \vec{a} = \frac{\Delta \vec{v}}{\Delta t} \) is a law

Therefore, in my opinion, \( \vec{a} = \frac{\Delta \vec{v}}{\Delta t} \) is not a law

(Credit will only be given if your reasons are stated)
You have the CHOICE between questions 10a, 10b, and 10c. Have a look at all three questions before you attempt one of these.

10b) Construct a timing device.

Assume you were given a workshop full of tools and raw materials of your choice. Your tasks are:

a) to build a timing device. This device is going to be used for measuring the duration in seconds of some activity as how long it takes a mouse to find its way out of a maze. The device has to be built such that, by measuring properties of its components using devices listed under b), the clock can be calibrated. If you wish, motors are available for use in your timing device. No electronic equipment is available.

b) to calibrate the device. For calibrating, you have instruments for measuring distances, masses, and forces. No instruments are available to measure times.
Restricting conditions: No signals for timing can be received from outside (e.g. observation of the sun or stars, duration of the day, frequency of AC power supply, "rpm"-data of motors, etc) No use may be made of the knowledge that \( g = 9.8 \text{ m/sec}^2 \). Determining "g" is not allowed as part of the calibration.

c) to measure the duration of the activity.

1) Draw a sketch of your timing device, and describe briefly how it works.
(Question 10b, continued)

2) State briefly which distances and/or masses and/or forces you are going to measure in order to calibrate your timing device, and how you calibrate it, in seconds. Give equations to substantiate your answer. (Remember: $g = 9.8 \text{ m/sec}^2$ "forbidden")

3) Describe how you would then measure the duration (in seconds) of the activity.
You have the CHOICE between questions 10a, 10b, and 10c. Have a look at all three questions before you attempt one of these.

10c) Excitation of atoms by atom-atom collisions

The energy stored in a helium atom excited to its first energy level above its ground state, is \( W = 3.2 \times 10^{-18} \) joules. It takes, therefore, \( W = 3.2 \times 10^{-18} \) joules to excite a helium atom. However, if one shoots a beam of helium atoms, each of K.E. = \( W = 3.2 \times 10^{-18} \) joules, into a container with helium gas, no excitations occur. (Actually, the energy has to be at least twice as much).

i) Explain why no excitations occur and substantiate your answer by the appropriate equations.

\[ \text{[5]} \]

ii) Explain why the K.E. of the atoms in the beam has to be at least \( 2 \times W \).

\[ \text{[5]} \]
APPENDIX F

Mid-Term II Examination
NAME  
(please print)  

REG. NUMBER  

MIDTERM EXAM, PHYSICS 110  SEC 1  
February, 1970  

1. This examination consists of 7 pages, front page included. Make sure you have a complete paper.  

2. Some of the questions are "multiple choice questions". If you would rather give an answer other than those provided please do so on the back of the page preceding the question. In these cases, do not forget to indicate "see back of preceding page".  

3. You have the choice to omit either question 5 or 6.  

4. You have the choice to omit one of the questions 7, 8 or 9.  

5. Please do not forget to give your name on this page and on the next page.  

6. DATA: mass of electron: 9.1 x 10^{-28} gm (= 9.1 x 10^{-31} kg)  
charge of electron: -4.8 x 10^{-10} statcoul (=-1.5. x 10^{-7}Coul)  
mass of proton: 1.67 x 10^{-24} gm (= 1.67 x 10^{-27}kg)  
charge of proton: +4.8 x 10^{-10} statcoul (= +1.6 x 10^{-19}Coul)  

DO NOT FILL IN!!

<table>
<thead>
<tr>
<th>1a</th>
<th>1b</th>
<th>2a</th>
<th>2b</th>
<th>3</th>
<th>4a</th>
<th>4b</th>
<th>4c</th>
<th>5</th>
<th>6a</th>
<th>6b</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>Total</th>
</tr>
</thead>
</table>
1. Definition of: Electric Field
   a) Give the definition as an equation:
   ________________________________ (3)

   b) Explain the symbols used:

2. Coulomb’s Law
   a) Give the law as an equation:
   ________________________________ (3)

   b) Explain the meaning of the symbols used:

3. Two points, A and B, are 10 cm apart on an electric field, E. If it takes 200 ergs to move an object with a charge of 5 statcoulombs from A to B, what is the potential difference between A and B?
4. A current I flows around a square wire loop of side length 1. The loop is placed in a homogeneous magnetic field \( B \), constant in magnitude and direction over the area of the loop. The direction of \( B \) is at right angles to the plane of the loop.

![Diagram of a square wire loop with magnetic field]

a) The total force acting on the loop due to I and \( B \) has the magnitude

\[ AHS \]

(b) The total force acting on the loop is in the direction:

- \( +x \)
- \( -x \)
- \( +y \)
- \( -y \)
- \( +z \)
- \( -z \)
- none of these

(c) The combined action of the forces acting on the four sides will turn the loop as indicated by arrow

- \( 1 \)
- \( 2 \)
- \( 3 \)
- \( 4 \)
- \( 5 \)
- \( 6 \)

- \( 1, 2, 3, 4 \)
- \( 5, 6 \)
- not at all.
5. The crew of a spaceship measures the electric field in the surroundings of a planet. Tracing out the electric field lines they found that each field line leaving the surface of the planet on one point re-enters the surface at another point. However, there are additional field lines, entering the surface of the planet and coming from infinity.

What conclusion can be drawn about the planet?

6. An electron moves in a region where there is a magnetic field, constant in magnitude and direction. What kind of path does the electron describe? (No electric or gravitational fields assumed.)

a) There is information missing to answer the question in an unambiguous way. Complete the question by making an additional assumption concerning the motion:

My additional assumption is:

b) From the question and the additional assumption, I conclude that the electron moves along a __________________________
YOU HAVE THE CHOICE TO Omit ONE OF THE QUESTIONS 7, 8 OR 9

8. In a first experiment, a proton moves with the speed \( v \) through point \( P \), in direction \( +x \). It experiences a force, \( F \), in direction \( +y \).

In a second experiment, a proton moves with twice the speed (i.e. \( 2v \)) through \( P \), in the same direction \( +x \). It also experiences a force in the direction \( +y \), the force however has half the magnitude, (i.e. \( F/2 \)) as compared to experiment 1.

An electric and/or magnetic field (assumed not to have changed between the first and the second experiment) was/were the cause of this force.

Check off the direction (or directions) of the field (or fields) that could have caused these forces:

**ELECTRIC:**
- \( +x \)
- \( -x \)
- \( +y \)
- \( -y \)
- \( +z \)
- \( -z \)
- No electric field

**MAGNETIC:**
- \( +x \)
- \( -x \)
- \( +y \)
- \( -y \)
- \( +z \)
- \( -z \)
- No magnetic field
YOU HAVE THE CHOICE TO OMIT ONE OF THE QUESTIONS 7, 8 OR 9

9. Pulling down a wall in an apartment, you find a single isolated copper wire, after the wall is down (see drawing). You suspect you might well cut the wire as some disconnected wires have been left in the walls after rewiring the apartment. To find out if the wire is still needed, you switch on all the electric equipment available using every electric outlet in the apartment. If the wire is part of the power network, it will now carry an alternating current, 60 cycles/sec. How could you find out, using Physics 110 lab or lecture equipment, whether or not there is an alternating current flowing through the wire?

(As you do not wish to damage the insulation of the wire, you cannot make direct electrical contact with the wire material. The ends of the wire are not accessible. The temperature rise in the wire due to the current would be too small to be detected.)

What could you do? (describe your actions and the results in detail)
APPENDIX G

Terminal Examination
THE UNIVERSITY OF BRITISH COLUMBIA  
Sessional Examination - April 1970  
PHYSICS 110 - Section 1  
(Mechanics, Electricity and Atomic Structure)  

TIME: 3 hours

PLEASE NOTE
1. This examination consists of 9 pages (including this page). Check that you have a complete paper.
2. You have the choice to omit:
   One of the questions 10 and 11
   One of the questions 12, 13, 14
   One of the questions 15, 16, 17
3. Please give your name, in print, and your reg. no. on this page and on the next page.

---

| 1a | 1b | 2a | 2b | 3a | 3b | 4a | 4b | 5a | 5b | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | Total |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|-----|
|    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |     |
1.a) Give a definition of FORCE (Classical Mechanics), as an equation:

b) Explain the symbols used:

2.a) Give a definition of MOMENTUM (Classical Mechanics), as an equation:

b) Explain the symbols used:

3.a) Give a definition of WORK (Classical Mechanics), as an equation:

b) Explain the symbols used:

4.a) Give a definition of ELECTRIC POTENTIAL DIFFERENCE, as an equation:

b) Explain the symbols used:

5. An object moves on a circle with constant speed.
   a) Give an equation for the force required to keep it in orbit:

   b) Explain the symbols used:

6. Give a relationship between the wavelength $\lambda$, the frequency $f$, and the speed of propagation $v$ of a wave:

   CONTINUED......
7. When the potential energy of a system increases there will also be an increase in mass. Give an equation governing this mass increase:

\[ (3) \]

8. Somebody claims that telepathic signals are a special kind of waves. What general kind of experiment would he have to perform to demonstrate that they actually are waves (in the meaning of the word "waves" as used in physics)?

(8)

9. Nuclear Energy can be converted into heat by nuclear fusion as well as by nuclear fission. Could one not make the best use of these processes by first splitting atoms (nuclear fission, heat will be produced), and then re-uniting the parts again (nuclear fusion, heat will be produced)? Repeating this cycle over and over again, one would have an inexhaustible energy source.

Explain, in terms of the binding energies of nuclei, why this process is impossible,
10. A radioactive sample explodes in a laboratory. Immediately after the explosion a Geiger counter in the room records 960 counts/sec. One day later, the same counter records 240 counts/sec. Assuming that a safe level of radiation as indicated by the counter would be 1 count/sec, what would be a reasonable estimate of the number of days since the explosion for people to safely re-enter the laboratory? (Give reasons with your answer)

11. A microphone stands at some distance from a wall. At some greater distance, a loudspeaker emits sound. The frequency of the sound is steadily increased beginning from zero, while the intensity of the sound is kept constant. When the frequency is below 1,500 cycles/sec, sound will be picked up by the microphone. At 1,500 cycles/sec, no sound is received. When the frequency is increased further, the microphone will pick up sound again.

a) Explain this phenomenon and b) predict at which higher frequency there will be the next minimum so that no sound will be received by the microphone.

a) EXPLANATION:

b) ANS: NEXT MINIMUM OCCURS AT: ___________ cycles/sec
You have the choice to omit one of the questions 12, 13 or 14

12. An indirect way for measuring currents (frequently used to measure strong current pulses) is to pass the current, $I_p$, through the primary coil of a transformer and to display the secondary emf, $e_s$, with an oscilloscope.

The current begins to flow at time $t_0$. The oscilloscope trace of the secondary emf, $e_s$, looks like this:

After careful consideration, give a qualitative graph of the primary current $I_p$.

You have the choice to omit one of the questions 12, 13 or 14

13. A proton moves, with steadily increasing speed, along a straight line (x-axis of a coordinate system). The only forces involved in this motion are caused by electric and/or magnetic fields. These electric and/or magnetic fields are constant in time and homogeneous in space.

Which one or more of the fields listed below has to be, or could be, present? (disregard signs. "along x-axis" means: in direction of + or - x)

- There has to be an electric field along the x-axis
- There could be an electric field along the x-axis
- There has to be an electric field along the y axis
- There could be an electric field along the y axis
- There has to be an electric field along the z axis
- There could be an electric field along the z axis
- There has to be a magnetic field along the x-axis
- There could be a magnetic field along the x-axis
- There has to be a magnetic field along the y axis
- There could be a magnetic field along the y axis
- There has to be a magnetic field along the z axis
- There could be a magnetic field along the z axis

If you would rather answer in a different way, please do so on the back of the preceding page.

continued...
YOU HAVE THE CHOICE TO OMIT ONE OF THE QUESTIONS 12, 13 or 14

14. Assume you bought a 100 Watt A.C. power supply specified to supply currents at a frequency of 50 cycles/sec. How could you test for the frequency using nothing else but some wire, and a calibrated stroboscope with adjustable frequency?

(Please explain your answer with the aid of a drawing.)
15. (A Spy vs. Spy episode) Passing the Black Spy's spaceship with a relative speed of 80% of the speed of light, the White Spy triggers a time bomb hidden in the Black Spy's ship. If the explosion is to occur 1,000 m distant from the White Spy's ship, at what time interval should the time bomb be set?

16. Space explorers discover a ring of charged particles orbiting around a mysterious cloud. The ring consists of positive hydrogen ions and negative oxygen ions, circulating in the same direction. The speed of the hydrogen ions is 1 km/sec, the speed of the oxygen atoms is 2 km/sec, the radius of orbit is the same for both kinds of particles. The number of particles per cubic meter is too small to allow the ions to combine. For the same reason, no electric or magnetic forces between the ions could account for the motion.

The explorers discuss the following explanations to account for the circular orbits of the ions. Try to rule out as many of these explanations as possible.

a) The circular orbits are due to gravitational attraction by a massive star within the cloud.

Could be □ cannot be □

Give reasons for your choice.
16. b) The circular orbits are due to a charged object hidden in the cloud.

[ ] could be  [ ] cannot be

Give reasons for your choice.

16. c) The circular orbits are due to a magnetic field at right angles to the plane of the orbits.

[ ] could be  [ ] cannot be

Give reasons for your choice.
YOU HAVE THE CHOICE TO OMIT ONE OF THE QUESTIONS 15, 16 OR 17

17. Design a device to (indirectly) measure the wavelength of a given ultraviolet spectral line. No use may be made of interference (as e.g. by using gratings, slits, standing wave patterns) or of refraction (e.g. as by using a prism).

Give a drawing of your design in sufficient detail. Explain what you observe with this device, and how you obtain the wavelength of the spectral line from your observations.