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A STUDY OF AN
OBJECTIVE PLACEMENT EXAMINATION
FOR SECTIONING COLLEGE PHYSICS CLASSES

by

John Milton Willson

A

THESIS

submitted to the Faculty of the
SCHOOL OF MINES AND METALLURGY
of the
UNIVERSITY OF MISSOURI
in partial fulfilment of the requirements
for the degree of
MASTER OF SCIENCE

Rolla, Missouri
1931

Approved: L. E. Woodman.
Professor of Physics

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To Professor L. E. Woodman, head of the Department of Physics at the Missouri School of Mines, the writer owes much for suggesting this study and making possible its completion. From its inception Dr. Woodman was ever ready to lend assistance and cooperation. Special mention should be made of his enthusiastic efforts in securing the cooperation of the various schools represented in the study.

To Professor C. V. Mann, head of the Department of Engineering Drawing, the writer is also indebted, especially for his encouragement and advice. Throughout the work Dr. Mann was quite willing to give of his time and professional experience in furthering the study. The writer also wishes to acknowledge the aid rendered by Dr. Mann in allowing free use of his personal and departmental library.

Acknowledgments are also due the seven high schools which cooperated in the preliminary study, and the departments of physics at Missouri University, Washington University, and Central College, through whose cooperation was obtained a set of papers sufficiently large to yield justifiable conclusions.

Introduction

For several years the Department of Physics of the Missouri School of Mines has practiced sectioning of its classes in general physics. The aim has been to segregate in one section the students of superior ability, giving them a course including both the fundamentals of physics and their applications in engineering. The remainder are given a course in fundamentals without placing so much stress upon the applications. This second group--the larger of the two--is further divided into two unequal groups, the smaller of which includes those students who are expected to encounter difficulty and need especial attention. The purposes of such division into sections are two:

1. To facilitate the instructional processes.
2. To give the superior student an opportunity to proceed without the sense of being held back by others of the group, and to give the less fortunate student an opportunity to proceed without the feeling of helplessness which is likely to be present when both types of students work in the same class.

It must be here understood that placing a student in a given section does not by any means predetermine or guarantee his grade. Each student is graded upon the type of work which he does. One would expect, however, from the considerations upon which the sectioning is done, that the grade averages of the two sections would differ.

Various criteria are used for determining the sections. The required physics courses are placed in the second year of all curricula at the Missouri School of Mines. This makes possible the use of a student's first-year record as a criterion for assigning him to a section. Another criterion used to supplement the first-year grade record is the student's score on the Iowa Placement Examinations. The physics examination consists of two parts, the Training Series and the Aptitude Series. These examinations are administered at the first two meetings of the class in general physics, the Aptitude Examination being given on the first day and the Training Examination on the succeeding day. The scores made on the two examinations are used in conjunction with the scholastic records of the freshman year to determine the sections.

Where the data from the placement examinations were used to supplement other fairly reliable data, it was thought that the administration of the Iowa

Examinations, requiring two periods, was wasteful of time. It was believed that an examination could be devised which could be administered in a single period and furnish information of sufficient worth. The MSM Physics Placement Examination was the result.

This investigation is concerned with a critical study of the examination. The aims of the study are to determine the probable worth of the examination as a unit and as compared with similar examinations.

Scope of Work Done

The historical development, purposes, and functions of placement examinations were studied, as were their form and construction. An objective type placement examination for college physics was constructed. This examination was administered to 113 high school students distributed among seven schools. The results were studied to determine the validity and the reliability of the examination. Slight revisions were made in the examination wherever need for them was apparent from the study of the high school papers. It was then administered to 510 college students distributed among four Missouri colleges and universities. From the group of papers thus obtained reliability coefficients and norms were determined for the examination. The worth of the examination for predicting accomplishment in college physics classes was studied by correlating the examination scores with the final term grades for each student. Regression equations were formed by which final or term grades could be predicted from the placement examination scores or from these scores and scholarship marks combined.

PART I

A Brief Survey of Placement Examinations

Functions of Placement Examinations

The chief function of the placement examination is prognosis. It is expected to yield results which will enable the administrator to predict with fair accuracy the character of work which a given individual is likely to do. It should afford a reasonable basis for sectioning a class into homogeneous groups in each of which all individuals would be expected to make somewhat the same progress. It should afford the instructor a useful device for establishing academic relations with his class at the first meeting of the group. It should indicate to the student something of the preparation he is assumed to have made for the work upon which he is entering and introduce him to the nature of the material of the course.

A Survey of Similar Investigations

During the last quarter century much attention has been directed toward prediction of academic success. The importance attached to such prediction is well expressed by Symonds in his Measurements in Secondary Education (7, page 363): "Science holds prediction as its most important aim and prognosis is the ultimate aim of endeavor in the scientific study of education."

Early studies of examinations for prediction had as their object the determination of general intelligence or the prediction of general mental attainment. The first tests designed to predict achievement in specific subjects or courses were constructed by T. L. Kelley, who published his results in 1914 (11). His aim was stated as follows: "The endeavor of this study is to predict with a known, and as high as possible, degree of accuracy the capacity of the pupil to carry a prospective high school course." He devised four tests to predict ability in algebra, geometry, history, and English. The correlations of the test scores with achievement grades ranged from .44 for the English test down to .31 for the history test. The reliability of the tests was probably rather low.

The next attempt of any importance to construct prognostic tests was that of Dr. Agnes Rogers, who began her work in 1916 and published her results in 1918. Correlations with achievement were much higher than those obtained by Kelley, running as high as .82. More will be said of her work later in this study.

From the beginning of the use of tests in prediction, two distinct types of tests have been utilized. One is the general psychological or intelligence test, while the other is the subject matter test which may be designed for prediction of general scholarship or more expressly for prediction in a given field. Intelligence tests which have been widely used in such studies are: Army Alpha, designed during America's participation in the European war for use in the U.S. Army; Terman Group Test of Mental Ability; Otis Group Intelligence Scale; Thurstone Psychological Examinations; the Brown Scale; and the Thorndyke Intelligence Test, especially designed to meet college needs. The average correlations of these tests with college marks as determined by various investigators are given in Table 1[1].

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[1] This table is adapted from Symonds: Measurements in Secondary Education, Table III, page 419, and from Stoddard: Iowa Placement Examinations, University of Iowa Studies in Education, Vol. III, No. 2, pages 11-12.

Table 1

Correlation of Intelligence Examination Scores with College Grades

Test	Jordan	McPhail	Toops	Hoke
Thorndyke		.50	.52	
Brown		.47	.40	
Thurstone		.33	.40	.125
Otis			.44	.06
Terman		.48	.45	.48
Army Alpha	.415	.39	.40	

Similar data for these and other placement examinations are given in Table 2.

Table 2

Predictions by Various Tests of First Semester Grade Averages in College[1]

Name of test	r	Source
Army Alpha	.45	Stone (1922)
Army Alpha	.44	Stone (1922)
Army Alpha	.33	Stone (1922)
Army Alpha	.50	Stone (1922)
Army Alpha	.41	De Camp (1921)

Table 2, continued.

Name of test	r	Source
Army Alpha	.49	Stoddard (1925)
Army Alpha	.44	McPhail (1924)
Army Alpha	.45	Colvin (1919)
Army Alpha	.35	Bridges (1922)
Army Alpha	.38	Bridges (1922
Army Alpha	.35	Bridges (1922)
Army Alpha	.28	Bridges (1922)
Army Alpha	.46	Van Wagenen (1920)
Thorndyke I-III	.60	Thorndyke (1922)
Thorndyke I	.47	Thorndyke (1922)
Thorndyke II	.45	Thorndyke (1922)
Thorndyke I-III	.51	Wood (1923)
Thorndyke	.53	McPhail (1924)
Thorndyke	.41	McPhail (1924)
Thorndyke	.41	McPhail (1924)
Thorndyke	.41	McPhail (1924)
Council on Education	.62	Stoddard (1925)
Council on Education	.54	Thurstone (1925)
Thurstone	.13	Hoke (1922)
Thurstone	.29	Thurstone (1922)
Minnesota	.63	Johnston (1924)
Terman Group	.48	Hoke (1922)
Brown University	.46	McPhail (1924)

Table 2, continued.

Name of test	r	Source
Brown University	.38	McPhail (1924)
Brown University	.39	McPhail (1924)
Brown University	.37	McPhail (1924)
University of Texas ..	.49	Perrin (1924)
Iowa Placement Examinations	.65 to .75	Stoddard (1926)
Iowa Physics Aptitude	.55	Willson (1930)
Iowa Physics Aptitude	.59	Willson (1931)
Mo. School of Mines Eng. Drawing	.63	Mann (1929)

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[1] Adapted from various sources, the chief one being Hammond and Stoddard: A Study of Placement Examinations, Bull. No. 15, Investigation of Engineering Education, S.P.E.E.

The tables indicate that the predictive value of the various examinations is quite variable and is in most cases undesirably low. It must be noted that the correlations given are between the examinations and average grades. When these tests are used to predict success in a single subject, results are even less satisfactory. C. L. Stone (17, pages 298-302) attempted to use Army Alpha for this purpose, obtaining coefficients of correlation ranging from .11 to .50. He tried to use the various parts of the test for guiding students in their choice of courses, but he determined that the test was valueless for such purposes.

The general conclusions derived from the work of various investigators concerning the use of intelligence examinations for prediction are:

1. Such examinations have more worth for predicting general academic success than attainment in specific subjects.
2. Such examinations are better for prediction of college success than are high school marks.
3. They are superior to subject-matter examinations for the prediction of general academic success, but inferior to such examinations for prediction of attainment in single subjects.

During recent years great development has been made of subject-matter examinations for general and specific predictive purposes. Outstanding are the tests prepared under the direction of Professor L. L. Thurstone in response to a demand made in a resolution passed by the Society for the Promotion of Engineering Education at its Baltimore meeting in June, 1918 (16):

> "That this society through its Committee on Admission, or otherwise, recommend that as a

> matter of experiment and research, psychological, 'objective', 'trade', or other similar tests be given to all students after admission to engineering courses of study and that the ratings thus obtained be compared with their subsequent scholastic success."

Six tests were prepared, five of which may be considered as subject-matter tests, while the sixth is the Thurstone Psychological Examination. Results obtained from administration to nearly eight thousand students entering engineering colleges are given in Table 3.

Table 3

Correlation between the Thurstone Group Tests and First Year Engineering Scholarship[1]

Test	r
Arithmetic	.38
Algebra	.42
Geometry	.30
Physics	.34
Technical Information	.23
Psychological Examination	.29

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[1] Engineering Education, Vol. XIII, No. 5, pages 263-318.

The complete series of tests given as a battery gave correlations running from .19 to .26, the median being .46. It was found that single tests in a specific subject were not of themselves very reliable bases for prediction of general academic success, but that they were more reliable than high school grades. It should be noticed that the Thurstone Group of tests did not propose to predict results in specific subjects.

Among the first studies devoted to a test for prognosis in a particular subject was that of Dr. Agnes Rogers (15, pages 72-74), referred to above. Dr. Rogers was interested in predicting mathematical ability in high school students. She prepared a battery of six diagnostic tests which she administered to a group of 114 students, all of whom were girls. Correlations obtained between the marks on the test battery and mathematics grades were .62 for one group of 53 individuals and .82 for another group of 61 individuals. These coefficients are quite high, but the working groups were not sufficiently large to assure their reliability.

The outstanding attempt at prediction in specific subjects is the series of tests known as the Iowa Placement Examinations constructed at the State University of Iowa by Dr. George D. Stoddard under the general direction of Dean C. E. Seashore of the Graduate College and Professor G. M. Ruch of the College of Education. These examinations constitute a series of educational tests designed to measure the training and aptitude of students for subjects commonly included in the first year of engineering curricula. Each subject is represented by two examinations: an aptitude examination which is a special kind of intelligence test, and a training examination which is an objective content examination. As outlined by the authors (10), the aptitude examination is designed to measure those particular mental abilities which probably constitute a factor in subsequent success in the particular subject, while the training examination measures the character of the previous training in the subject, also, the amount of previous training. The Society for the Promotion of Engineering Education cooperated in the study of the Iowa Examinations by having the examinations given to students in a large number of schools throughout the country, thus amassing considerable data on the validity and reliability of the examinations. Their accuracy of prediction is shown in Table 4. It will be noted that the correlation coefficients in this table are relatively higher than those in Table 1, page 8, which gives correlations between general intelligence examinations and general scholastic success.

Table 4

Correlation between Iowa Placement Examinations and First Semester Grades in the Subject[1]

Examination	Mean coefficient	Range of coefficients
Chemistry Aptitude	.48	.23 to .63
Chemistry Training	.52	.25 .67
Chemistry Aptitude plus Chemistry Training	.52	.35 .65
English Aptitude	.46	.35 .69
English Training	.54	.28 .67
English Aptitude plus English Training	.52	.33 .74
Foreign Language Aptitude	.52	.36 .73
French Training	.56	.45 .65
Spanish Training	.53	.48 .57
Mathematics Aptitude	.46	.16 .65
Mathematics Training	.51	.34 .65
Mathematics Aptitude plus Mathematics Training	.51	.37 .71
Physics Aptitude	.47	.28 .62
Physics Training	.61	.57 .69

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[1] Adapted from *A Study of Placement Examinations*, Bulletin 15, Society for the Promotion of Engineering Education.

A comparison of true worth can be made, however, only between the data given above for the Iowa Examinations and similar data concerning examinations used to predict in a single subject. Table 5 furnishes such a comparison. A study of Tables 4 and 5 leads to the conclusion that the Iowa Examinations excel.

Table 5

Prediction by Intelligence Tests of First Semester Grades in Specific Subjects in College[1]

Description of test	r	Source
University of Texas (Chemistry)	.30	Stoddard
Thorndyke I (Chemistry)	.27	Stoddard
Thorndyke I (Chemistry)	.41	Stoddard
University of Texas (English)	.54	Perrin
Thorndyke I (English)	.42	Stoddard
Thorndyke I (English)	.36	Stoddard
University of Texas (Mathematics)	.36	Perrin
Thorndyke I (Mathematics)	.23	Stoddard
Thorndyke I (Romance Language)	.25	Stoddard
University of Texas (Physics)	.31	Perrin
Mo. School of Mines (Drawing)	.63	Mann

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[1] Adapted from various publications.

Description of the Missouri School of Mines Physics Placement Examination

The examination is divided into four parts. Part One measures the elementary mathematical processes used in physics. It contains thirty items which belong to two distinct types. Some of the items are tests in logic designed to measure the ability of the student to draw conclusions from given observations. The majority of the items measure the simple arithmetic and algebra involved in problems frequently occuring in a course in college physics.

Part Two is essentially an interest test. Its form might be called pictorial recognition. It consists of thirty-four sketches or diagrams of devices involving some common important physical principle. The pictures are numbered consecutively. They are accompanied by a list of the names of the devices illustrated. These names are arranged in random order with a blank before each in which the student is to place the number of the corresponding sketch. While this part to some extent presupposes a partial knowledge of elementary physics, it is expected that the majority of students will have acquired more of this information through their various individual associations than through formal instruction, and the extent of knowledge displayed by the student in this part of the examination should be a measure of his interest in applied physics. It is logical to assume that interest in a subject will be a factor in success in the subject.

Part Three is made up of three selections of material from a standard textbook in college physics written especially for technical schools. Based upon these selections is a set of precisely worded true or false statements which are intended to measure the ability of the student to grasp and utilize what he has read. One of the selections makes use of a lettered diagram in order to test the student's ability to make use of the pictures and diagrams that supplement his text.

Part Four is also essentially an interest test. It is held that the student who has particular fitness and liking for physics will have built up a fund of knowledge through his reading and other activities, and that the extent of this fund of knowledge will be a measure of probable scholastic success in the subject. Accordingly, Part Four is made up of thirty statements involving fundamental concepts of physics and their application. The recognition type of question with choice of answer to be made from five offered was used in order to eliminate as completely as possible the effects of chance answers.

The entire test consumes forty-eight minutes of actual working time, distributed as follows: Part One, fourteen minutes; Part Two, eight minutes; Part Three, fifteen minutes; Part Four, ten minutes.

PART II

Results of Administration to High School Students

Introductory Statement

The examination was administered in the spring of 1930 to 113 high school pupils distributed among seven schools. Approximately ninety-five per cent of the 113 pupils were seniors within a few days of graduation. The remainder, with one exception, were juniors. One sophomore who expressed a desire to take the examination was permitted to do so. His score was the second highest from his school and relatively high among the 113 scores.

The aims for administering the test in the high schools were:

1. To obtain a set of papers to serve as an evaluation index for the examination.
2. To discover any inherent defect in content, arrangement, time limits, etc.
3. To determine what differences, if any, the examination might bring out between students who had taken a course in physics in the high school and students who had not taken such a course.

The Missouri schools cooperating in the study and the number of students used from each were as follows: Rolla, (45); St. James, (18); Pacific, (12); Sullivan, (11); Webster Groves, (12); Salem, (8); Dixon, (7). All the students were boys except one of the Webster Groves group and sixteen of the Rolla group. Of these girls who were permitted to take the examination, six had completed a course in high school physics.

Discussion of Norms

Norms are standards which enable comparisons between individual scores, group scores, or the scores of individuals and group scores. A student's accomplishment may be compared with that of his class; one class may be compared with another; one instructor's results with another's, etc.

Norms in general are of two types--measures of central tendency and measures of variability. Most important among the former are the mean, the median, the quartiles, and the percentiles. Most important among the latter are the quartile deviation, the average deviation, and the standard deviation. The latter is most often used. The particular measure to be used will depend upon the purpose for which it is to be used. It is quite possible for one type of measure to be of little value for comparative purposes, while another type has great value. For example, two sets of measures might have the same mean, but the distributions be such that the standard deviation of one be twice that of the other. Obviously, comparison of the means of the two sets of measures accomplishes nothing; we must utilize some measure which will furnish a comparison of the variation of the trait being measured in the two groups from the average of the trait for each group. The standard deviation is such a measure.

The distribution, mean, median, and range of the scores made by the composite high school group are given in Table 6.

Table 6

Means, Medians, and Ranges Obtained from Papers Written by High School Students

Group	N	Mean	Median	Range[1]
Entire	113	61.85	57.0	113-17
High School physics	45	80.8	81.0	113-44
No H. S. physics	68	48.33	46.5	98-17

---

[1] Maximum range is 126-0.

The arithmetic mean is quite satisfactory, considering the nature of the examination and the nature of the groups to which it was administered. The ratio between the mean score and the perfect score compares quite well with this ratio for various examinations of the same general type as the examination being studied. The ratio mean score ÷ perfect score is .49. This ratio for the Iowa Placement Examinations ranges from .37 for the Chemistry Training Examination to .62 for the English Aptitude Examination.

For a perfect distribution, that is, one following the normal probability curve, the mean and median scores should be identical. They actually differ by 4.85 points and by seven test papers. Increasing the number of cases would likely cause the mean and median scores to approach each other.

Variability norms obtained for the high school distribution are given in Table 7.

Table 7

Variability Norms for High School Group

Norm	Value
Quartile deviation	15.6
Average deviation	21.8
Standard deviation	24.03

Critical Study of the Examination

Among other questions which this preliminary investigation with high school students attempts to answer are the following: (1) Is the examination sufficiently valid? (2) Is it reliable? (3) Does it detect sufficient differences in student ability to be used as a criterion for sectioning classes?

A worthwhile examination must have high validity. Ruch (2) defines validity as follows: "By validity is meant the degree to which a test or examination measures what it purports to measure. Validity might also be expressed more simply as the 'worth-whileness' of the examination." He states further, "For an examination to possess validity it is necessary that the materials actually included be of prime importance, that the questions sample widely among the essentials over which complete mastery can reasonably be expected on the part of the pupils, and that proof can be brought forward that the test elements (questions) can be defended by arguments based on more than personal opinion." The chief methods of validation for this test were analysis of text books and courses of study, analysis of similar examinations, and judgement of competent persons. The content of the examination is such that it should have high validity.

Comparison of the scores made by students having a high school course in physics with the scores made by students not having such a course indicates that the examination does contain sufficient matter pertaining to knowledge of physics to be selective. Consequently, one may expect that among students who have had no advance preparation the higher scores will be made by individuals having a natural liking for things of a physical nature. It is reasonable to assume that such students will have a better chance of survival than other types, and it should be a function of this type of test to discover such students.

Reliability is a highly important criterion of a good examination. Ruch (2) defines reliability as follows: "By reliability is meant the degree to which a test or examination measures what it really does measure, not necessarily what it purports to measure. Reliability is synonymous with accuracy of measurement. In mathematical terms it is often identical with self-correlation, or the extent to which two samples of the same thing, e.g., ability in arithmetic, yield the same numerical scores."

The reliability of the test and its various parts as calculated by standard statistical procedure is quite satisfactory. The reliabilities are given in Table 8.

Table 8

Reliability Coefficients

Part	r_x	r_∞
One	.905 ± .021	.951
Two	.949 ± .012	.974
Three	.896 ± .023	.946
Four	.892 ± .024	.944
Entire	.966 ± .0044	.988

These coefficients were obtained by the chance-half method of correlation. The 113 scored papers were split into two hypothetical forms by summing separately the scores on the even-numbered and odd-numbered items. Pearson product moment coefficients of correlation were then obtained between these two forms. This gave the reliability of one-half the test. The reliability of the entire test was then determined by substituting n = 2 in the Spearman (Brown) prophecy, formula, which is:

$$r_x = \frac{nr}{1 + (n-1)r}$$

in which r is the coefficient of correlation between the half forms.

The column in the above table headed "r_∞" gives the index of reliability. This is the coefficient of correlation between a set of obtained scores and their corresponding true scores, the true score of an individual being the average of a large number of measurements made of the given individual on the same or duplicate tests under precisely the same conditions. The index of reliability is also the maximum value which the reliability coefficient r_x can take. This follows from the statement by Kelley (12, page 327) "....the highest possible correlation which can be obtained (except as chance might occasionally lead to higher spurious correlation) between a test and a second measure is with that which truly represents what the test actually measures, --that is, the correlation between the test and true scores of individuals in just such tests." Kelley has shown (13, pages 34-71) that the correlation between a series of obtained scores and their corresponding "true" scores may be found from the formula

$$r_\infty = \sqrt{r_x}$$

in which r_x is the reliability coefficient obtained from duplicate forms of the same test. Since the value of r_x can never be greater than unity, it is seen that the index of reliability can never exceed unity. The values of r_∞ obtained in this study are quite high.

Comparison of the quartile range (31.2) with the total range (96) indicates that the examination has high selectivity which will enable high, medium, or low

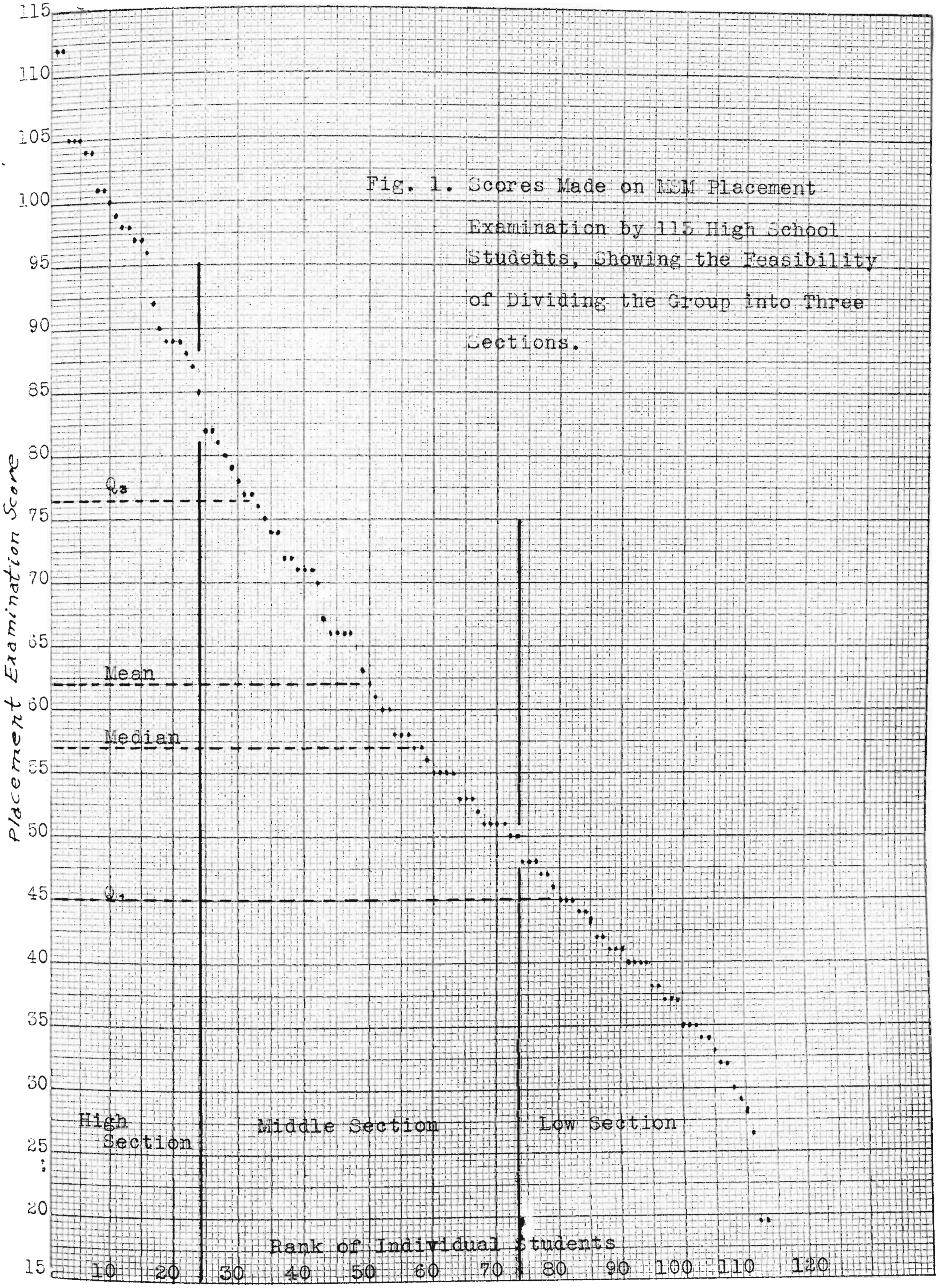

Fig. 1. Scores Made on MSM Placement Examination by 115 High School Students, Showing the Feasibility of Dividing the Group into Three Sections.

sections to be determined from the results of its administration to a large group of students. This is well indicated graphically by the appended curve, Fig. 1. The validity of these results for sectioning must be determined from a study of their use for that purpose.

The preliminary investigation revealed a few mechanical faults which could be and were corrected before the examination was prepared in final form for administration to college students. It was found that the arrangement of parts was not perhaps most advantageous for administration to high school students. Part One seems to have been the hardest and Part Three the easiest for high school pupils, and these parts perhaps should have been interchanged for the best psychological effect. In an attempt to discover the apparent cause of the difficulty of Part One for high school students the writer discussed that part with a number of the students taking the examination. The general opinion was that they had forgotten much of their algebra, which most of them had completed approximately three years previously. The explanation appears rather lame, however, in view of the simple nature of the mathematics involved in Part One. Inasmuch as the students of the Missouri School of Mines will have completed a year of freshman mathematics before the examination is administered to them, it is thought that for these students the original arrangement of parts should prove satisfactory.

The time limits as set seemed to be quite satisfactory. In general, the omissions were well scattered throughout the answers to the test items rather than concentrated near the ends of the various parts. This would indicate that the omissions were due chiefly to ignorance of the answer rather than to lack of time. Sixty-three of the students took the examination under the direct supervision of the writer, who noticed few evidences of insufficient or surplus time.

A summary of the statistical analysis of the high school papers is given in Table 9 on the following page.

Table 9

Statistical Data on the Examination Papers Written by High School Students

N (Number of cases)	113
Maximum possible score	126
Minimum possible score	0
Range	113-17
Arithmetic mean	61.85
Median score	57
Upper quartile	76.3
Lower quartile	45.1
Quartile range	31.2
Quartile deviation	15.6
Average deviation	21.8
Standard deviation (S.D.)	24.03
Probable error of a score	4.578
$P. E._{score} \div S.D.$	0.18
r_x, coefficient of reliability	$0.966 \pm .0044$
r_∞, index of reliability	0.988
$r_x \div S.D.$	0.041

PART III

Results of Administration to College Students

Introductory Statement

The examination was administered to high school students merely to obtain material for a preliminary study as outlined in Part II. With such a group the test is probably an ''aptitude'' examination to a greater degree than with the college group. With the latter the examination becomes more of the nature of a training test, since the students have had greater opportunity to learn something of the material over which the testing is done. Since the examination is to be used with college groups for prognostic purposes, its value as a prognostic test can best be determined by administering it to a group of college students and studying the results.

Accordingly, after a few slight changes had been made in the examination where need for them was pointed out by the set of high school papers, an edition was prepared for administration to college students. The examination was administered in September, 1930, to a class of 130 second-year men students at the Missouri School of Mines. This group of papers served as a basis for an exhaustive study of the test, results of which will be found on succeeding pages.

To secure a supplementary group of papers arrangements were made with the departments of physics at Washington University, Missouri University, and Central College to give the examination to their basic physics classes at the first meeting of each class. The Washington University group of 213 students was approximately two-thirds first-year engineers. The Missouri University group consisted of 118 individuals, approximately all of whom were engineering students. The Central College group of 49 students was comprised chiefly of students of liberal arts, some of whom were women.

The final standing of each student at the end of the term was obtained to determine the degree to which the student's accomplishment might be predicted by his placement examination score.

Distribution of Scores

The scores obtained on the examination indicate a tremendous variation in the skills and abilities tested. The total number of students taking the test was 510. The score frequencies for this group are given in Table 10. That the examination adequately measures differences of individual performance is graphically shown by Fig. 2.

Table 10

Frequency Distribution of Scores

(Frequency column gives the number of students whose scores fell within corresponding score groups in adjacent column.)

Score group	Frequency
35-39	1
40-44	5
45-49	6
50-54	5
55-59	13
60-64	20
65-69	36
70-74	45
75-79	63
80-84	41
85-89	57
90-94	48
95-99	47
100-104	42
105-109	43
110-114	22
115-119	15
120-124	1

N = 510

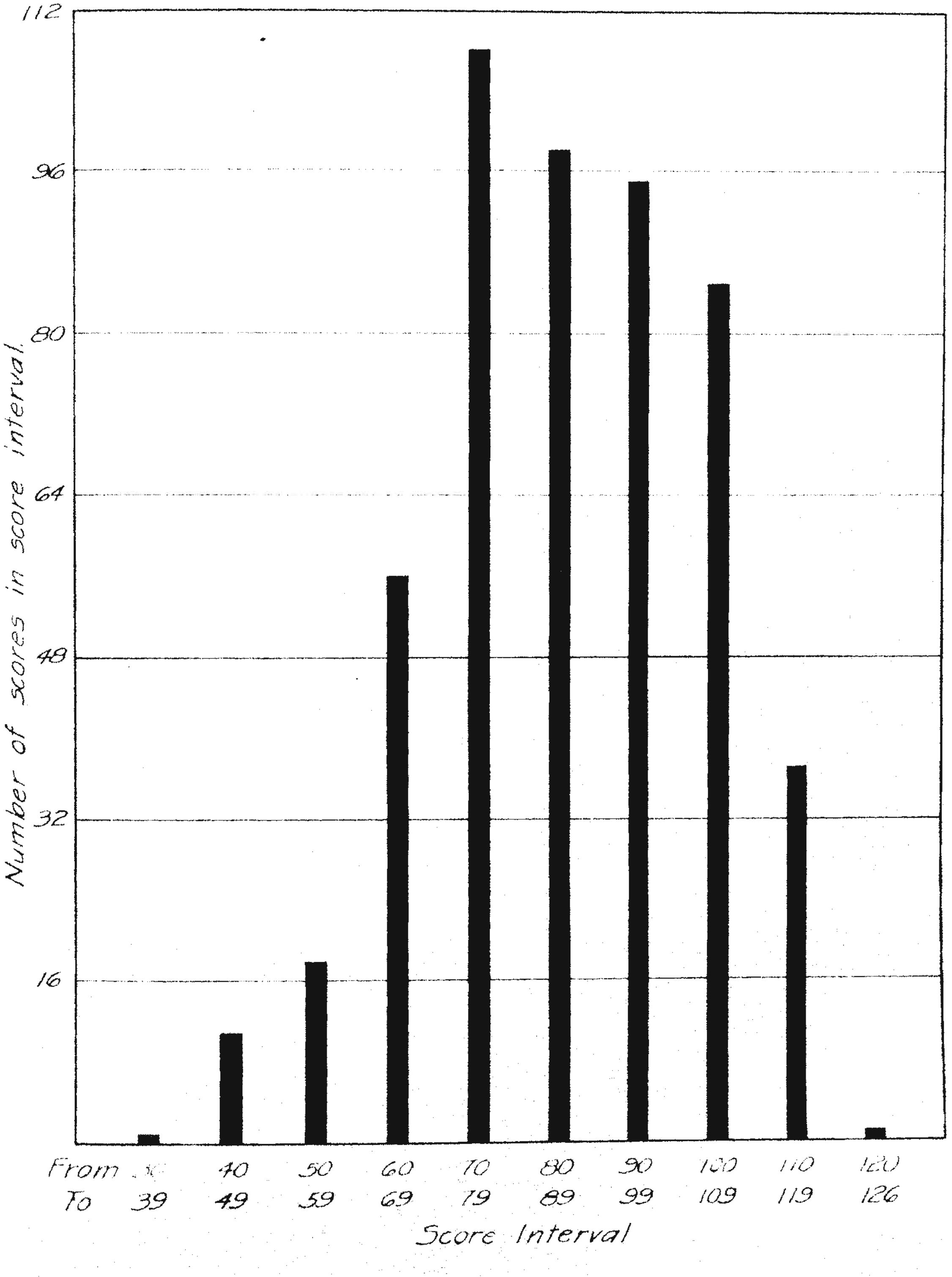

Fig 2. Distribution of scores made by 510 college students on the examination

Norms for the College Group

Norms are measures by which the results of a test may be compared with the results of other tests. The meaning and use of the various norms are discussed on page 21. Table 11 gives percentile norms and means for the composite college group and for the groups from the four different schools. All papers in a given group were used to determine the norms for that group.

Table 11

Percentile Norms and Medians for College Groups

	Composite	Missouri Mines	Missouri U.	Wash. U.	Central College
N	510	130	118	213	49
Mean score	84.28	81.27	84.17	91.46	72.91
Percentiles:					
10	65.14	65.0	66.0	70.83	41.25
20	71.77	68.25	75.77	76.2	55.0
25 (Q_1)	74.61	70.0	78.08	78.4	58.33
30	76.74	72.0	80.5	80.79	63.33
40	81.22	75.94	86.0	86.39	70.0
Median	86.75	79.05	90.0	93.21	75.0
60	91.46	85.29	93.66	98.48	79.0
70	96.81	88.88	96.43	103.18	85.0
75 (Q_3)	99.52	91.36	98.55	105.48	87.5
80	102.5	94.09	100.55	107.03	89.16
90	108.49	101.66	105.71	113.75	95.0

Variability norms for the college groups are given in Table 12. All papers written by a given group were used in calculating the norms for that group.

Table 12

Variability Norms for College Groups

Norm	All	M.S.M.	Mo. U.	W. U.	Cantral
Quartile deviation	12.45	10.68	10.23	13.54	14.08
Average deviation	13.04	11.87	13.24	14.07	14.91
Standard deviation	16.72	14.05	16.19	16.24	17.33
No. of papers	510	130	118	213	49

Reliability of the Examination

Table 13 gives reliability coefficients and indexes of reliability for the examination and each of its four parts as determined from the 130 papers written by students at the Missouri School of Mines. The meaning of these coefficients and the method of their calculation are discussed on pages 25 to 28 in the account of the preliminary investigation with high school students.

Table 13

Reliability of the Examination

Part	r_x	r_∞	PE_{rx}	$PE_{r\infty}$
One	.822	.907	.019	.0103
Two	.924	.967	.008	.004
Three	.866	.939	.015	.007
Four	.879	.937	.013	.007
Entire	.881	.938	.011	.007

The probable errors in the last columns of the table are the probable errors of the coefficients due to random sampling of cases. They were determined from the formula

$$PE_r = \frac{1 - r^2}{\sqrt{N}}$$

in which r is the coefficient and N is the number of cases from which it was determined. A probable error of, say, .01 for a coefficient of .80 signifies that the chances are even that the value of the coefficient lies between .79 and .81. It may be inferred that as the number of cases becomes larger the value of PE_r becomes smaller.

The probable error of an individual score may be obtained by use of the formula

$$PE_{score} = .6745 \text{ SD} \sqrt{1 - r}$$

in which SD is the standard deviation of the measures and r is the reliability coefficient of the examination. For the Missouri School of Mines group the PE_{score} was found to be 3.87. This may be interpreted as follows: The chances are fifty out of a hundred that an obtained score of, say, 50 on the examination represents a true score of 50±3.87, or, expressed in another way, fifty per cent of the obtained scores are in error (as compared with their true scores) by not more than ± 3.87 points.

Comparisons of probable errors for a single score for different examinations will not give a comparison of reliabilities unless the size of the scale unit for each examination is the same. If the probable error is divided by the standard deviation, this factor is equalized. This ratio, $\frac{PE_{score}}{SD}$, is a good comparative measure of reliability. The smaller this ratio, the more efficient is the examination. The ratio $\frac{PE_{score}}{Mean}$ is also sometimes used to compare the reliabilities of different tests, but is usually not so well regarded as the other.

The reliability measures of the examination are compared in Table 14 with similar measures for various other examinations. The close agreement of the figures indicates satisfactory reliability for the Missouri School of Mines physics examination.

Table 14

Reliability Data for Various Tests

Test	N	SD	r_x	PE_{score}	PE_{score}/SD
M.S.M. Physics	130	16.7	.88	3.9	0.23
M.S.M. Drawing	160	22.0	.81	6.41	.29
Iowa Phy. Apt.	100	19.0	.89	4.2	.22
Iowa Phy. Tr.	100	24.4	.85	6.4	.26
Iowa Chem. Apt.	100	17.5	.88	4.0	.23
Iowa Chem. Tr.	100	28.0	.93	5.1	.18
Iowa Math. Apt.	100	7.0	.86	1.7	.24
Iowa Math. Tr.	100	10.4	.88	2.4	.23

Another method of indicating the reliability of the different parts of an examination is the coefficient of correlation between the parts of a test and the entire test. Generally speaking, a part which shows low intercorrelation with other parts but high correlation with the whole test is desirable. Inter-part correlations will usually not be relatively high because the different parts of a test usually contain different kinds of material. High inter-part correlation is likely to indicate that the two parts represented by the coefficient measure the same trait, and the only advantage obtained by using both parts is the greater reliability secured from the increased length of the test.

Interpart correlations are given in Tables 15a to 15e. The results given for Missouri University, Central College, and the Missouri School of Mines were obtained from the entire group of test papers from each school. The data of Table 15a were obtained from a chance sample of one hundred papers chosen alphabetically from the college groups, the number chosen from each being proportional to the number of papers in the group. Alphabetical sampling was also used to obtain one hundred papers from the Washington University group to obtain the data of Table 15c.

Table 15a

Interpart Correlations, All Colleges

	Part 1	Part 2	Part 3	Part 4	Total
Part 1	----	.319	.379	.563	.637
Part 2	.319	----	.298	.346	.823
Part 3	.379	.298	----	.516	.713
Part 4	.563	.346	.516	----	.852
Total	.637	.823	.713	.852	----

Table 15b

Interpart Correlations, Mo. School of Mines[1]

	Part 1	Part 2	Part 3	Part 4	Total
Part 1	<u>.822</u>	.205	.387	.508	.609
Part 2	.205	<u>.924</u>	.343	.591	.877

Table 15b, continued

	Part 1	Part 2	Part 3	Part 4	Total
Part 3	.387	.343	.866	.502	.627
Part 4	.508	.591	.502	.879	.875
Total	.609	.877	.602	.895	.881

---

[1] Underlined figures are part reliabilities discussed on page 38.

Table 15c

Interpart Correlations, Missouri University

	Part 1	Part 2	Part 3	Part 4	Total
Part 1	----	.362	.357	.522	.697
Part 2	.362	----	.289	.554	.814
Part 3	.357	.289	----	.608	.720
Part 4	.522	.554	.608	----	.783
Total	.697	.814	.720	.783	----

Table 15d

Interpart Correlations, Washington University

	Part 1	Part 2	Part 3	Part 4	Total
Part 1	----	.289	.417	.535	.642
Part 2	.289	----	.439	.503	.853
Part 3	.417	.439	----	.563	.619
Part 4	.535	.503	.563	----	.873
Total	.642	.853	.619	.873	----

Table 15e

Interpart Correlations, Central College

	Part 1	Part 2	Part 3	Part 4	Total
Part 1	----	.802	.332	.515	.623
Part 2	.802	----	.156	.587	.747
Part 3	.332	.156	----	.468	.627
Part 4	.515	.587	.468	----	.875
Total	.623	.747	.627	.875	----

Comparison of Results Obtained from College Group having High School Physics and College Group not Having High School Physics

It is to be expected that the student who has successfully completed a course in physics in the high school might obtain a higher score on the examination than the student who has not completed such a course. This, perhaps, is the desirable thing; it is reasonable to assume that the average student who enters a course in college physics should be better prepared to pursue the work if he has successfully completed a high school course than if he has not had such a course. If this hypothesis be valid, it may be inferred that a placement examination designed for sectioning purposes should be able to differentiate between the two classes of students.

The papers obtained from the various colleges were studied to determine to what extent the examination might differentiate between the two classes of students. Of the 510 students who took the examination, 492 indicated whether or not they had taken a high school physics course. Of this number 362 had completed the high school course, while 130 had not.

The frequency distribution of scores for the two groups is given in Table 16. Direct comparison of the data given in the table is facilitated by Fig. 3, which shows the per cent of each group having scores within given deciles of the range.

A study of Table 16 reveals an interesting situation. From the thirtieth up through the seventieth decile it is noted that the larger per cents are found in the group which did not have physics in high school. Beginning with the eightieth decile and continuing through the remainder of the table it is noted that the larger per cents are found in the group which had physics in high school. If the decile intervals of the score range of the examination be considered approximate measures of the intelligence levels of the groups falling within the respective deciles, it may be concluded that the general class of students electing high school physics is composed of students of superior mental ability.

Table 16

Frequency Distribution of Scores Made by College Students Having Physics in High School and College Students not Having Physics in High School

Score	Number		Per cent	
Interval	No H.S. Physics	H.S. Physics	No H.S. Physics	H.S. Physics
30-39	1	0	.8	0
40-49	9	3	7.0	.8
50-59	15	3	11.5	.8
60-69	25	31	19.2	8.5
70-79	43	62	33.1	17.1
80-89	15	78	11.5	21.6
90-99	13	75	10.0	20.7
100-109	6	76	4.6	21.0
110-119	3	33	2.3	9.1
120-126	0	1	0	.3
Totals	130	362	99.9	99.9

Measures of variability and central tendency for both groups are given in Table 17. It must be remembered in comparing these measures that the group having high school physics was about three times the size of

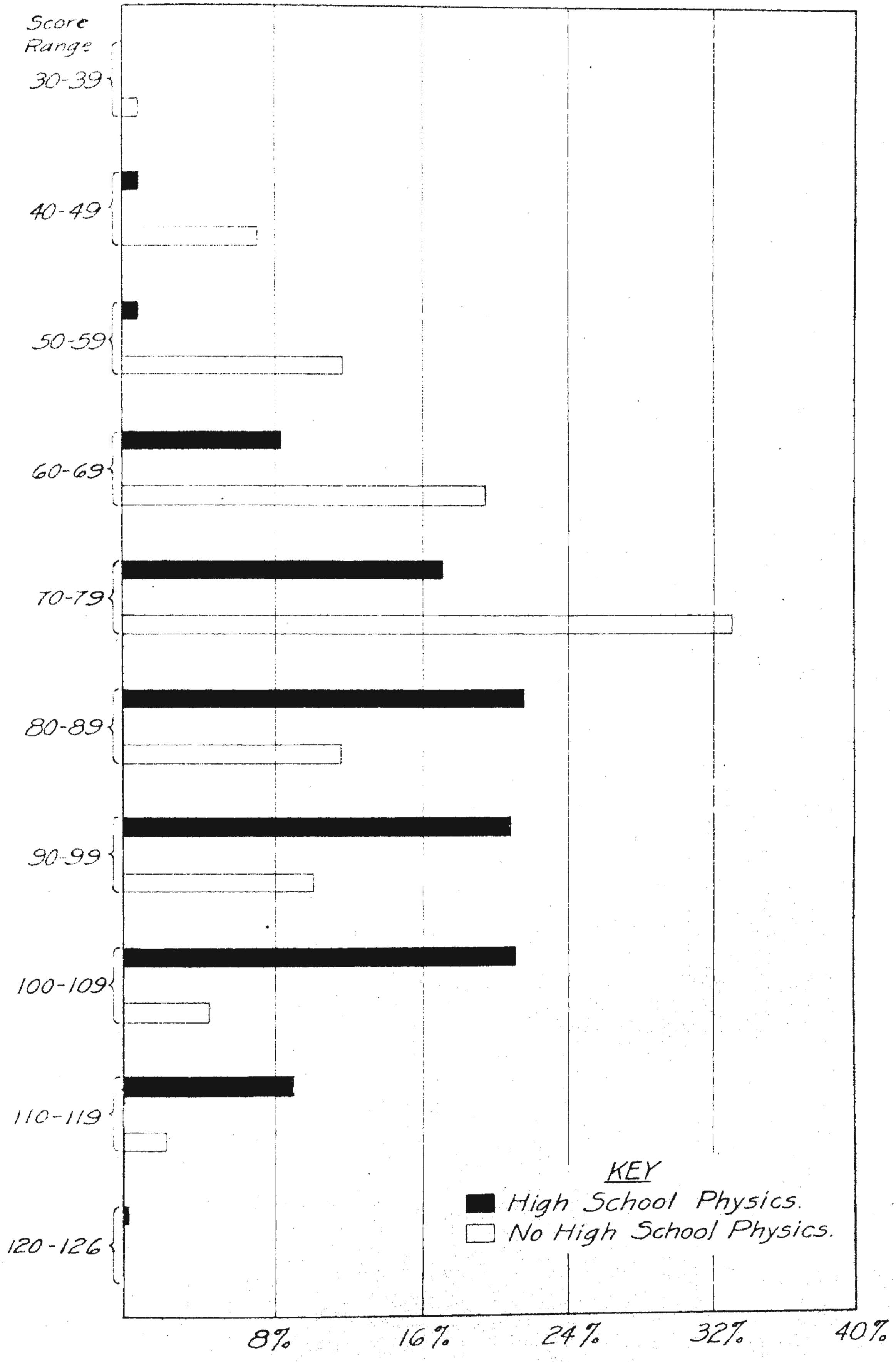

Fig 3. Comparison of distribution of scores made by group having Physics in high school and group not having Physics in high school.

the other. Measures for the entire group are also given for purposes of comparison.

Table 17

Measures of Central Tendency and Variability for College Groups Having and not Having High School Physics and for the Composite Group

Measure	Group having H.S. physics	Group not having H.S. physics	Composite group
Mean	90,14	74.15	84.28
Median	90.52	73.26	86.75
Q_1	78.87	63.88	74.61
Q_3	102.57	85.42	95.52
A.D.	12.68	12.53	13.04
S.D.	15.23	16.45	16.72
PE_{score}[1]	3.53	3.82	3.87
$PE_{score}/S.D.$	.23	.23	.23

---

[1] $PE_{score} = .6745\ S.D.\ \sqrt{1 - r}$, where r is the reliability coefficient. The reliability coefficient used is that obtained from the entire group of Missouri School of Mines papers.

The group of papers written by Missouri School of Mines students was studied to determine the effect of a high school physics course on the number of correct answers appearing for each item. It was found that on the majority of the items of the test the per cent of correct answers given by the group having physics in high school was larger than the per cent of correct answers given by the group not having high school physics. There was little difference apparent for Part Three of the test; the greatest differences appeared on Parts Two and Four. These differences were expected, in view of the nature of the material contained in these parts. A complete tabulation of these data is rather lengthy to indlude here; it is given at the close of the paper in Appendix A.

It now becomes necessary to test the hypothesis that completion of a high school course in physics contributes to the student's ability to proceed with college physics.

It is evident that the results obtained from the examination indicate differences between students who have studied physics in high school and those who have not. A study of the final grade distributions for the two groups reveals only slight differences in the per cent of each group receiving the same letter grades. A study of failures and withdrawals likewise indicates few differences. Sixty-five of the test group were reported as failures and forty-five as withdrawals.

Of the failures, forty-five had studied physics in high school while twenty had not. Of the withdrawals, twenty-seven had studied physics in high school; eighteen had not. The ratios between these numbers are roughly the same as that between the total numbers of the two groups.

From these considerations it might seem that completion of high school physics has little to do with subsequent success in college physics. The apparent value of the high school physics course will be approached from another point of view presented in the next section.

PART IV

Quality of Preliminary Training as Shown by the Results of the Examination

Analysis of the examination papers throws considerable light upon the quality of preparation with which the student enters upon his course in college physics. Careful analysis was made for this purpose of the 130 papers written by Missouri School of Mines Students. This group of students is representative of varied types of high schools, consisting as it does of students from both rural and urban communities scattered among many different states. Of the 130 students comprising the group, 96 had completed a course in physics in the high school, and the entire group presumably had completed a course in trigonometry during the freshman year in college.

Table 18 gives the number of correct and incorrect answers and the number of times omitted for some selected questions from Parts One and Four of the examination. The results from the two groups of students, those having high school physics and those not having high school physics, are tabulated separately for purposes of comparison. These are typical questions dealing with fundamental physical laws, concepts, and processes, and are thought to be representative of the entire examination.

Table 18

Student Accomplishment upon Selected Items from the Examination

	High School Physics				No High School Physics			
Item	No. right	No. wrong	No. omitted	% right	No. right	No. wrong	No. omitted	% right
				Part One				
1	60	27	9	63	17	11	6	50
2	39	41	16	41	11	17	6	32
3	3	71	23	3	1	27	5	neg.
4	17	21	58	18	7	10	17	21
5	33	20	43	34	13	11	10	38
6	87	5	4	91	31	2	1	91
				Part Four				
1	54	42	0	58	14	17	3	41
2	31	33	32	32	8	12	14	24
3	58	38	0	60	23	3	8	67
4	29	65	2	30	8	21	5	24
5	39	41	16	41	9	9	16	26
6	36	60	0	37	10	20	4	29

The test items referred to in the first column of the above table are given in full below.

Table 18a

Test Items Referred to in Table 18

Part One

Item 1. $S = 1/2\ at^2$. Solve for t.

2. $1/2mv^2 = mgh$. Simplify and solve for v.

3. Express in symbols: m is proportional to the cube of b.

4. Solve (to one decimal place): $120\left(\frac{273}{330}\right)\left(\frac{770}{760}\right)$.

5. What is the mean of 1, 4, 0, 5, 5?

6. Express in symbols: P_1 is to P_2 as V_2 is to V_1.

Part Four

(Multiple answers from which the best is to be chosen)

1. A common unit of mass is the (1) liter, (2) cubic foot, (3) centimeter, (4) gram, (5) erg.

2. The quantity commonly indicated by 'g' is (1) acceleration of gravity, (2) gas constant, (3) ionization constant of gases, (4) universal gravitational constant, (5) temperature gradient.

3. The ampere is the unit used for expressing (1) resistance, (2) electric current, (3) electrical conductance, (4) electromotive force, (5) potential gradient.

4. The time rate of change of position of a body is known as (1) force, (2) acceleration, (3) speed, (4) rotation, (5) displacement.

Table 18a, continued

5. The quantity of heat liberated by unit mass of water upon freezing is called (1) specific heat, (2) mechanical equivalent of heat, (3) latent heat of fusion, (4) radiant heat, (5) latent heat of vaporization.
6. The velocity of a body may be expressed in (1) foot pounds, (2) dynes, (3) grams per second, (4) miles per hour, (5) feet per second per second.

Little comment need be made on the figures given above; they speak plainly for themselves. The differences between the accomplishment of the two groups--those having physics in high school and those not having physics in high school--are not very great. One must conclude that the high school training in physics must be of little value as a foundation for college physics. However, it was pointed out earlier in the report (page 44) that in the lower deciles of the score range there was a greater per cent of students who had not taken physics in high school, while in the higher deciles there was a greater per cent of students who had taken physics in high school. This may indicate that the upper stratum of students do profit from their high school physics course, or it may indicate as stated above that those students electing high school physics in general fall in the upper intelligence level groups.

Obviously, if a student enters upon his college physics course unable to find the mean of a set of simple observations, or to do the simple multiplications and divisions needed for the solution of a problem based upon the general gas equation, or to express symbolically a simple proportionality, he must of necessity spend a great part of his time in acquiring mechanical skills and processes, leaving him less time for the acquisition of general information. What can the student who dees not recognize the simple definition of speed or a common unit of velocity be expected to know of the physics of motion? What does the student know of the physics of heat who does not know the meaning of the latent heat of fusion? Can the student's knowledge of electricity be very extensive if he does not recognize the practical unit of current? It would seem from the results of the examination that the teacher of college physics may not assume much initial knowledge of physics on the part of most of his students. This agrees with the conclusion reached by Hammond and Stoddard (10) in their study of the Iowa Examinations: "-----we fear-----that the college teacher of physics cannot assume any beginning knowledge on the part of most of his class. -------- this is the actual case in most institutions, and the teaching of physics to engineering students is adjusted accordingly."

A general idea of the extent of the preliminary training of a group may be obtained by noting the character of the answers to the various test items. The response to each item was tabulated for the Missouri School of Mines group of 130 students. It was found that the results of the twelve selected items discussed above were fairly representative of the entire examination, except for Part Three. This part requires no previous preparation except the ability to read fairly difficult text material. The summary giving the right, wrong, and omitted responses is given in Appendix C, as it is deemed rather long for inclusion here.

PART V

Use of the Examination for Prognosis

Predictive Power of the Examination

The chief purpose for which the examination is designed is to predict the quality of future scholastic performance and afford the instructor a basis for sectioning his classes. In order to accomplish this purpose the examination must differentiate sharply between students and yield scores over a considerable range. That it does this has been previously shown (pages 33-35). To be useful for prognosis the differences between students detected by the examination must be closely associated with the differences in subsequent accomplishment.

The simplest mechanical procedure for predicting is to arrange the test scores in sequence and divide them into thirds or quarters, as preferred. A better method, perhaps, is to plot the scores in descending order and make arbitrary divisions where distinct breaks occur in the curve. Fig. 4 gives such a graphical representation of the scores made on the examination by 130 students at the Missouri School of Mines and indicates how the curve may be used to divide the group into three sections. If the examination has

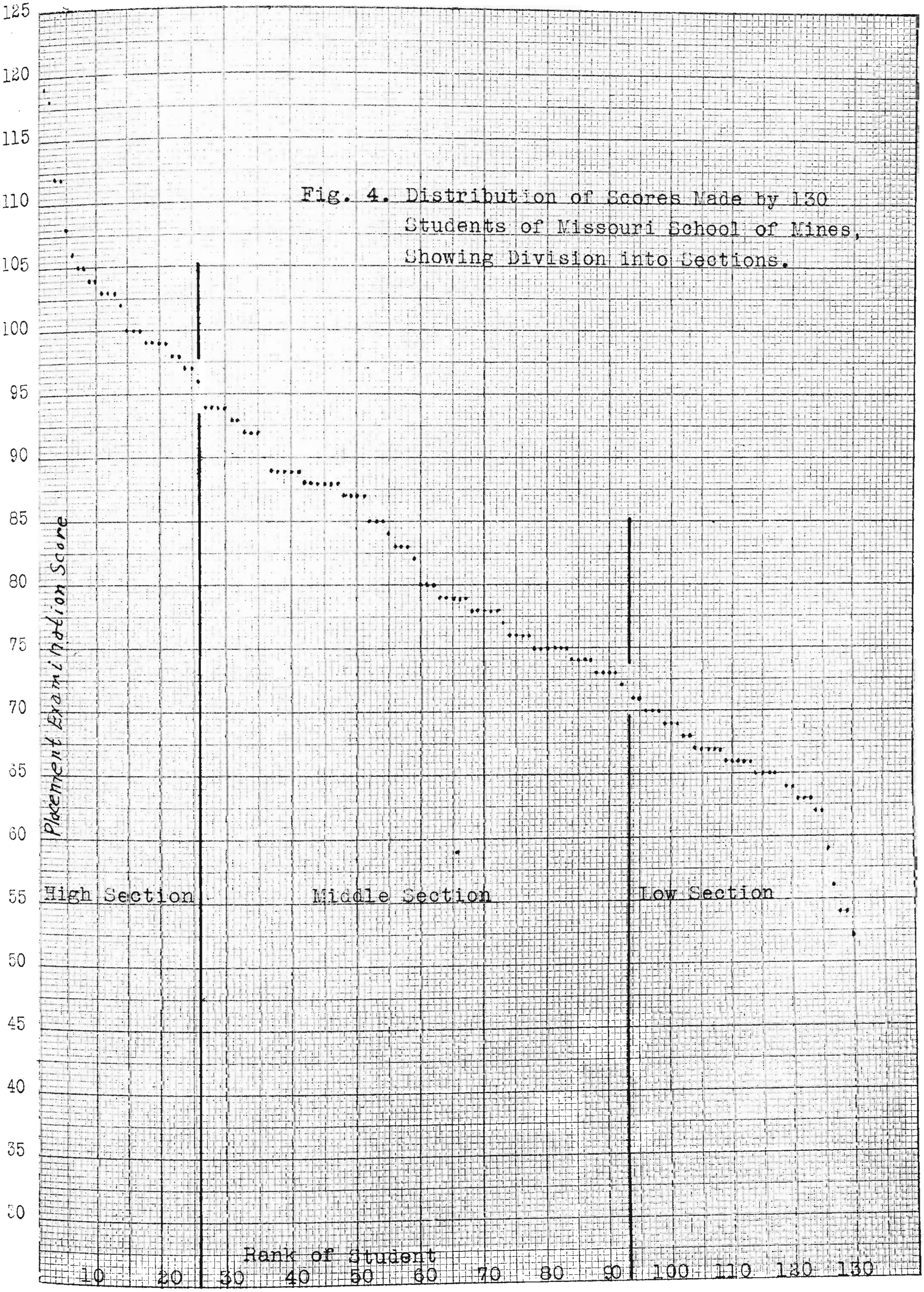

Fig. 4. Distribution of Scores Made by 130 Students of Missouri School of Mines, Showing Division into Sections.

any predictive worth, it is to be expected that the upper group thus determined will contain those individuals who are likely to lead the class in success in the subject, while the lower third or fourth should contain those students who will encounter difficulty and are most likely to fail in the course. The validity of this method of sectioning on the results of the placement examination is well shown in Table 19, which gives the first semester grades made by students falling in various quarters of the group according to placement examination scores. The tabulation represents 416 students distributed among the four cooperating colleges.

Table 19

Distribution of Grades in Physics Made by Students Falling in Quarters of the Class as Determined by Placement Examination

(All figures give per cents)

Quarter of class in placement scores	Semester grades in physics		Pass %	Non-pass %
	E,S (A,B)	M,I (C,D)		
1 (high)	41.7	52.2	93.9	6.1
2 ------	18.3	75.6	93.9	6.1
3 ------	20.0	60.0	80.0	20.0
4 (low)	6.1	66.1	72.2	27.8

The above table indicates noticeable scholastic superiority of the upper quarter, scholastic inferiority of the low quarter, and medium accomplishment of the middle quarter. This is about the distribution which is usually desired or expected in the various sections of a given class of any size. A similar tabulation for each school is given in Table 20.

Table 20

Distribution of Grades Made by Students Falling in Quarters of the Class

(All figures give per cents)

Quarter of class in placement scores	Semester grades in physics		Pass	Non-pass
	E,S (A,B)	M,I (C,D)		
	Missouri School of Mines			
1	47	53	100	0
2	23	73	96	4
3	14	76	90	10
4	3	77	80	20
	Missouri University			
1	58	42	100	0
2	11	89	100	0
3	26	63	89	11
4	0	81	81	19

Table 20, continued

Quarter of class in placement scores	Semester grades in physics		Pass	Non-pass
	E,S (A,B)	M,I (C,D)		
	Washington University			
1	31	63	94	6
2	31	51	82	18
3	23	52	75	25
4	10	67	77	23
	Central College			
1	20	80	100	0
2	10	74	84	16
3	10	55	65	35
4	0	55	55	45

Each section of the above table is quite similar to the table representing the composite group in that it points out the different abilities of the various quarters. The set of papers from Washington University affords an interesting additional study, inasmuch as it represents three groups of students. Two groups of approximately fifty students each are comprised of liberal arts and premedical students respectively. The third group, containing approximately one hundred individuals, is made up of engineering students. Table 21 shows the grade distribution for these three groups.

Table 21

Distribution of Washington University Grades

Quarter of class in placement scores	Semester grades in physics		Pass	Non-pass
	A,B %	C,D %	%	%
	Liberal arts group			
1	61	39	100	0
2	29	71	100	0
3	15	77	92	8
4	21	64	85	15
	Premedical group			
1	20	80	100	0
2	40	50	90	10
3	30	60	90	10
4	0	54	54	46
	Engineering group			
1	29	63	92	8
2	24	64	88	12
3	24	48	72	28
4	4	42	46	54

The engineering group differs somewhat from the other two in the grade distribution. The failures are more numerous and are not so well concentrated in the lower quarters as they are in the liberal arts and premedical groups. The reasons for this are not apparent. The writer is not sufficiently well acquainted with the three courses taken by these groups to estimate any probable effect due to the content or presentation of the courses. The course taken by the engineers contains more material and leads to more credit than the courses taken by the other students.

Another common way to determine the accuracy of prediction is to use the Pearson coefficient of correlation between two measures, the two in this case being the placement examination scores and the term grades. The higher the coefficient, the closer is the agreement between the two correlated measures. A coefficient of 1.0 represents perfect agreement, 0 represents just no agreement, and -1.0 represents complete divergence or disagreement between the two sets of measures. Table 22 gives the values of this coefficient for each of the four groups of papers obtained for this study. It will be noted that two values are given for the Missouri School of Mines group. The first is the correlation coefficient between the placement examination scores and the semester grades given as per cents, while the second is the coefficient between the placement soores and the semester grades expressed in the conventional letter system used by the school for expressing final grades. The coefficient for the Central College group makes use of per cent grades. The others are based on letter grades.

Table 22

Pearson Coefficients of Correlation between Placement Examination Scores and Grades

Group	Cases	r
Missouri School of Mines	117	.569
Missouri School of Mines	117	.522
Missouri University	101	.584
Washington University	148	.665
Central College	44	.663

In interpreting such coefficients as those in the above table it must be remembered that the value of the coefficient must be dependent upon what is to be predicted. If the examination were to predict actual rank of students in the class, as, for example, to say that a certain individual should be third or seventh or twentieth in a class, a coefficient of .5 perhaps is not significant. However, if the thing to be predicted is merely in what letter group a certain individual will fall, a coefficient of .5 is quite satisfactory and indicates that the placement examination may be used with considerable accuracy in predicting scholastic achievement. (10, page 703)

Regression Equations for Prediction

Regression equations may be utilized in predicting an individual's most probable standing in a group of measures from his standing in another set of measures. A regression equation is the equation of a line expressing the dependence of one variable upon another. If the variables be designated as x and y, the equations of the regression lines may be expressed as

$$y = r \frac{\sigma_y}{\sigma_x} x \quad \text{and } x = r \frac{\sigma_x}{\sigma_y} y$$

where r is the Pearson coefficient of correlation between the two measures and σ_x and σ_y are the standard deviations of the two sets of measures. The above equations are expressed in deviation form. They are often more conveniently used when expressed in score form. The score form may readily be obtained from the deviation form by standard procedure. Thus expressed, the equations are

$$Y - Y' = r \frac{\sigma_y}{\sigma_x} (X - X') \text{ or } Y = r \frac{\sigma_x}{\sigma_y} (X - X') + Y'$$

and

$$X - X' = r \frac{\sigma_y}{\sigma_x} (Y - Y') \text{ or } X = r \frac{\sigma_x}{\sigma_y} (Y - Y') + X'$$

where X' and Y' are the means of the two distributions and X and Y are any individual x- and y- scores.

To set up a regression equation for prediction in this study, the placement examination results from a group of 118 Missouri School of Mines students were used as the x-variable and the corresponding semester grades as the y-variable. Means and sigmas for the two sets of data were calculated to be

$$X' = 85.67, \quad Y' = 76.31, \quad \sigma_x = 12.75, \quad \sigma_y = 9.33.$$

The correlation coefficient between the two was found to be 0.569. Substitution of these values in the Y regression equation stated above gives

$$Y - 76.31 = .569 \frac{9.33}{12.75} (X - 85.67)$$

which upon simplification gives

$$Y = .4164X + 40.64.$$

This equation may be used to "predict" the most probable score, or term grade, of any individual whose score on the placement examination is known. By plotting the line which this equation represents upon a system of coordinate axes in which abscissae represent placement examination scores and ordinates represent term grades, the prediction of grades becomes merely a mechanical process of reading values from the graph. This procedure is illustrated by Fig. 5.

The above determined regression equation was used to predict term grades for each placement examination

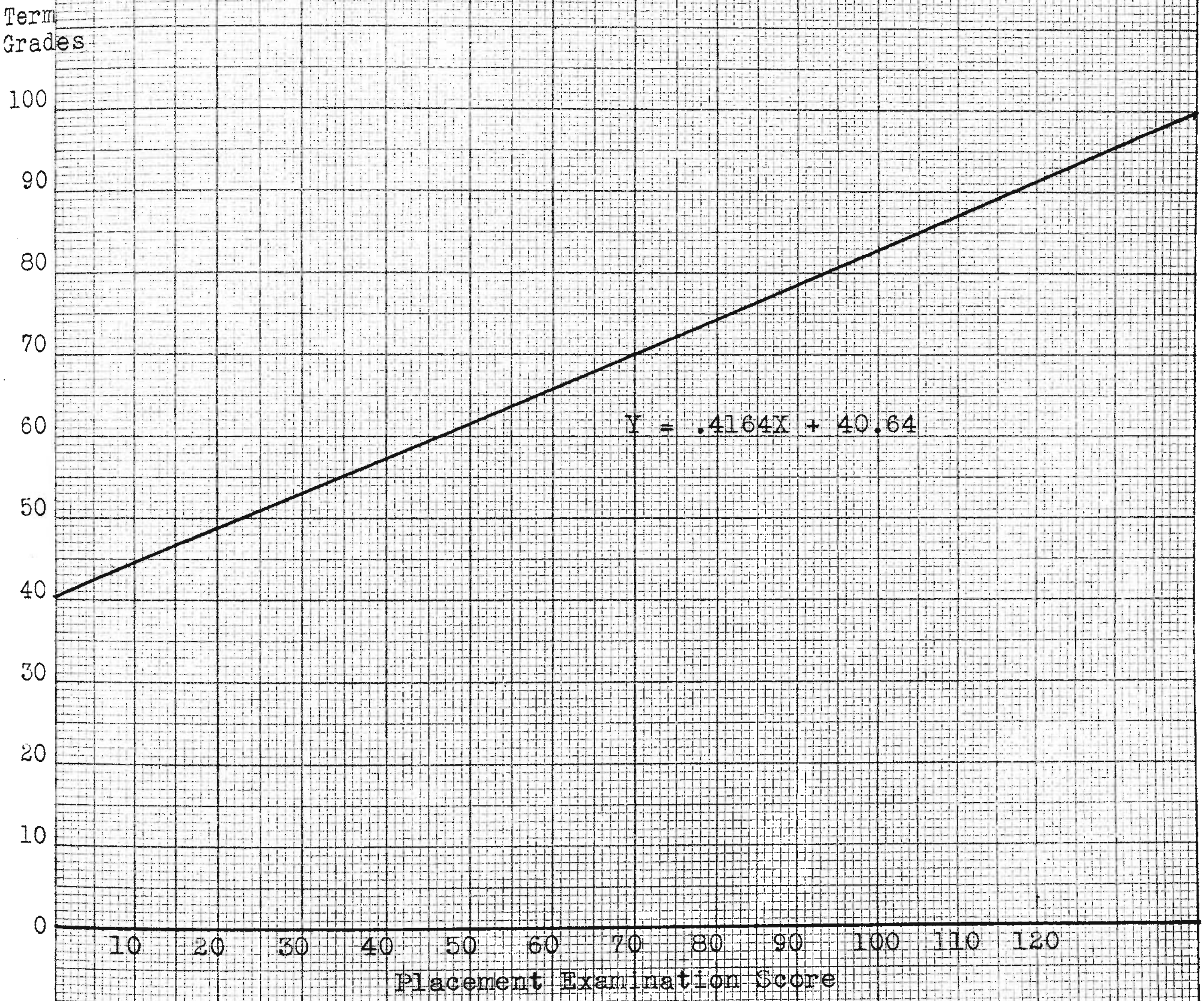

Fig. 5. Regression Line for Predicting Grades.

score represented in the sets of papers written at Missouri University, Washington University, and Central College. These predicted grades were then compared with the earned grades by computing the correlation coefficients between the two sets of marks. The results are given in Table 23.

Table 23

Correlation between Predicted Grades and Earned Grades

Institution	No. of cases	r
Missouri University	108	.636 ± .038
Washington University[1]	148	.307 ± .050
Central College	43	.548 ± .071
Washington University[2]	95	.531 ± .049

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[1] Includes all students.

[2] Includes liberal arts and premedical students but not the engineering students.

The predicted grades were referred to above as "most probable". The probable error of these predicted grades can be shown by calculating the standard error of estimate, which may be expressed as

$$\sigma_{(est.)} = \sigma_y \sqrt{1 - r^2}$$

where σ_y is the standard deviation of the y-distribution and r is the coefficient of correlation between x and y. Substituting the numerical values for σ_y and r gives

$$\sigma(\text{est.}) = 9.33\sqrt{1 - .569^2} = \pm 6.12$$

The significance of this standard error of estimate will now be discussed. By the use of the regression equation a term grade of 82 can be predicted for an individual whose placement examination score is 100. It may now be said that the most probable term grade for this individual is 82 with a $\sigma_{(est.)}$ of ± 6.12, and that the chances are 68 to 100 that the actual term grade for the individual will fall between the limits of 76 and 88. The predicted grade corresponding to a score of 60 on the placement examination is 65. Then the chances are 68 in 100 that the individual scoring 60 will have a term grade between the limits of 59 and 71.

In general, the value of prediction will depend upon the size of the error of estimate, the fineness of the units of measurement, and the purposes for which the prediction is made. The prediction for which this examination is devised need not be exact -- it needs only to locate an individual in a given quarter or third of his class. In view of this fact, consideration of the foregoing discussion indicates that the examination can be used for prediction with a fair degree of success.

In the early pages of this report mention was made of the fact that the students entering the physics classes at the Missouri School of Mines have completed one year of college work. This makes available grade averages for use in helping to section a class. Such use can best be effected by building a regression equation involving three variables whereby a student's most probable term grade can be predicted from his placement examination score and his first year scholastic average. A regression equation of this sort can be developed by the technique of partial correlation. The development of such an equation is discussed briefly in summarized form below. The methods used in obtaining the partial and multiple correlations are those discussed in Statistics in Psychology and Education by Garret (4). Subscript notation is used to refer to the variables, 1 being term grades, 2 the grade average, and 3 the placement score.

Step I.

(1) Term grades.	(2) Grade Averages.	(3) Placement scores.
$M_1 = 77.35$	$M_2 = 1.16$	$M_3 = 82.2$
$\sigma_1 = 9.64$	$\sigma_2 = .73$	$\sigma_3 = 15.03$
$r_{12} = .73$	$r_{13} = .57$	$r_{23} = .49$

Step II. Calculation of partial coefficients of correlation.

$$r_{12\cdot3} = \frac{r_{12} - r_{13}r_{23}}{\sqrt{1 - r^2_{13}}\ \sqrt{1 - r^2_{23}}} = .628.$$

$$r_{13\cdot2} = \frac{r_{13} - r_{12}r_{23}}{\sqrt{1 - r^2_{12}}\ \sqrt{1 - r^2_{23}}} = .358.$$

$$r_{23\cdot1} = \frac{r_{23} - r_{12}r_{13}}{\sqrt{1 - r^2_{12}}\ \sqrt{1 - r^2_{13}}} = .132.$$

Step III. The regression equations.

$$x_1 = b_{12\cdot3}\ x_2 + b_{13\cdot2}\ x_3 \quad \text{(Deviation form)},$$

or $$X_1 = b_{12\cdot3}\ X_2 + b_{13\cdot2}\ X_3 \quad \text{(Score form)}.$$

in which $b_{12\cdot3} = r_{12\cdot3} \dfrac{\sigma_{1\cdot23}}{\sigma_{2\cdot13}}$ and $b_{13\cdot2} = r_{13\cdot2} \dfrac{\sigma_{1\cdot23}}{\sigma_{3\cdot12}}$.

Step IV. Calculation of sigmas.

$$\sigma_{1\cdot23} = \sigma_1 \sqrt{1 - r^2_{12}}\ \sqrt{1 - r^2_{13\cdot2}} = 6.13.$$

$$\sigma_{2\cdot13} = \sigma_2 \sqrt{1 - r^2_{23}}\ \sqrt{1 - r^2_{12\cdot3}} = .493.$$

$$\sigma_{3\cdot12} = \sigma_3 \sqrt{1 - r^2_{23}}\ \sqrt{1 - r^2_{13\cdot2}} = 12.2.$$

Step V. Regression coefficients and the regression equation.

Substituting for $r_{12\cdot3}$, $r_{13\cdot2}$, $\sigma_{1\cdot23}$, $\sigma_{2\cdot13}$, and $\sigma_{3\cdot12}$ gives

$$b_{12\cdot3} = 7.81 \quad \text{and } b_{13\cdot2} = .179.$$

This gives the equations

$$x_1 = 7.81x_2 + .179x_3 \text{ (Deviation form)}$$

and

$$X_1 = 7.81X_2 + .179X_3 + 53.58 \text{ (Score form).}$$

Step VI. Calculation of the standard error of estimate.

$$\sigma(\text{est. } x_1) = \sigma_{1.23} = \pm 6.13$$

$$PE_{(\text{est. } x_1)} = .6745\ \sigma_{1.23} = \pm 4.13$$

Step VII. The coefficient of multiple correlation.

$$R_{1.(23)} = \sqrt{1 - \frac{\sigma^2_{1.23}}{\sigma^2_1}}$$

The regression equation is expressed above in two forms--the deviation form and the score form. The latter is the more convenient of the two in that raw scores may be used, thereby avoiding the tedious arithmetical calculations necessary before the deviation form can be applied. By means of this equation, having at hand a student's grade point average (X_2) and his placement examination score (X_3), one can calculate the most probable grade which the individual is likely to obtain in college physics. Two examples will make the use of the equation clear. Suppose a student has a grade point average of 2.00 and makes a score of 100 on the placement examination. Substitution of $X_2 = 2.00$ and $X_2 = 100$ in the regression equation gives

$$X_1 = 7.81 \overset{*}{\pm} 2.00 + .179 \times 100 + 53.58 = 87.1.$$

Therefore, using the given criteria as the basis of estimate, the most probable grade this individual is likely to receive is 87.1. Again, suppose a student has a grade point average of 1.00 and a score of 75 on the placement examination. Substituting and solving as before, this student's most probable term grade is found to be 74.81.

The grades predicted above are referred to as most probable. Their reliability may be expressed by the standard error of estimate or the probable error of estimate given in Step VI of the summary above. The predicted term grade of 87.1 has a probable error of estimate of 4.13. This means that the chances are even that this student's grade will not be lower than 82.97 or higher than 91.23. The reliability of any other grade estimate may be found in the same manner.

The coefficient of multiple correlation, $R_{1(23)}$, is numerically the coefficient of correlation between the set of measures actually made of a variable trait and the set of measures of this variable predicted by means of the regression equation. Mathematically, $R_{1(23)}$ is the correlation between the dependent variable (1) and the two independent variables (2) and (3) taken together. R as obtained above in Step VII is .772. This means that if the most probable term grades were predicted by the regression equation for, say, two hundred students, the correlation between these two hundred predicted grades and the two hundred grades actually made by these students will be .772. This, then, is a measure of how closely term grades in physics are related to grade point averages and placement examination scores taken together.

Inasmuch as grade point averages were not available for the students in the cooperating schools, it was impossible to predict grades by means of this regression equation involving two independent variables and determine the actual correlation between such predicted grades and earned grades.

PART VI

Comparison of the Examination with the Iowa Physics Aptitude Examination

The Iowa Physics Aptitude Examination was administered to the Missouri School of Mines group of students in order that the results obtained from the MSM examination might be compared directly with those obtained from a standardized examination. A comparison of the results is given below.

The scale unit of the two examinations is different. The range for the Iowa examination is 0-175; that of the MSM examination is 0-126. In order that the two sets of data might be more directly comparable, the scores on the Iowa examination were expressed in terms of the scale of the MSM examination; This was done by dividing each Iowa score by the ratio between the two perfect scores, 175/126.

The scores obtained on the Iowa examination were relatively higher, as shown by Table 24 and Fig. 6. Both distributions are skewed, but in opposite directions. The form of the two curves in Fig. 6 indicates that the MSM examination should be more selective in the upper part of the range, while the Iowa examination perhaps should be the more selectige in the lower part

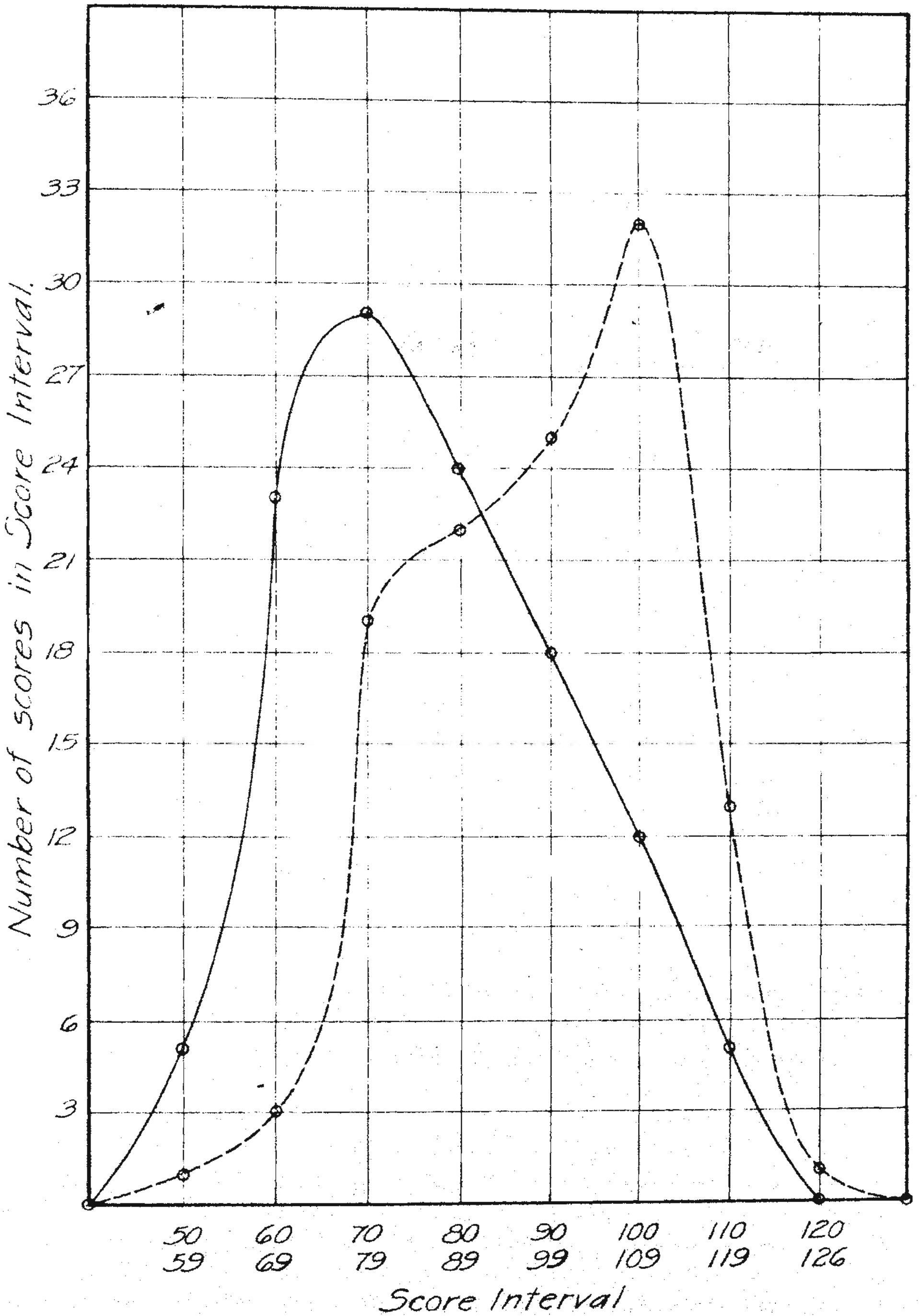

Fig. 6 Frequency distribution of scores made on the Iowa and M.S.M. eximinations by 116 Missouri School of Mines students.

of the range. Consequently, the former should be of the greater value in forming a section of superior men.

Table 24

Distribution of Scores Made on Iowa Physics Aptitude and MSM Physics Placement Examinations by 116 Missouri School of Mines Students[1]

Score interval	Frequency of scores	
	Iowa exam.	MSM exam.
50-59	1	5
60-69	3	23
70-79	19	29
80-89	22	24
90-99	25	18
100-109	32	12
110-119	13	5
120-126	1	0

---

[1] Iowa scores converted, as explained on page 74.

Measures of central tendency and variability are given for the two sets of measures in Table 25. Central tendency measures for the Iowa examination are much the larger, as would be expected from Fig. 6, while little difference can be noted in the variability measures.

Table 25

Measures of Central Tendency and Variability for the Sets of Scores in Table 24[1]

Measure	Iowa exam.	MSM exam.
Mean	93.95	81.27
Median	95.20	79.05
Q_1	82.73	70,0
Q_3	105.31	91.36
Quartile deviation	11.29	10.68
Average deviation	11.79	11.87
Standard deviation	14.18	14.05
PE_{score}	3.19	3.87
$PE_{score} \div$ S.D.	.22	.23
Correlation with term grades	.59	.57

---

[1] Converted Iowa scores used.

Comparison of the coefficients of correlation between the placement examination scores and the term grades favors the Iowa examination slightly. On the other hand, Table 26, showing the distribution of term grades falling in quarters of the class as determined by the placement examination scores indicates a slight advantage of the MSM examination for prediction.

Table 26

Distribution of Grades Made by Students Falling in Given Quarters of the Class as Determined by the Iowa Examination and by the MSM Examination

(All figures express per cents)

Quarter	Iowa Examination				MSM Examination			
of class	E-S	M-I	Pass	Non-pass	E-S	M-I	Pass	Non-pass
1 high	48	52	100	0	47	53	100	0
2 ----	21	79	100	0	23	73	96	4
3 ----	14	58	72	28	14	76	90	10
4 low	7	86	93	7	3	77	80	20

SUMMARY AND CONCLUSIONS

A survey of attempts at prognosis by means of placement examinations revealed that much work had been done with varying success. Such examinations were found to be better for prediction of college success than were either attainment in a specific subject or high school marks. It was revealed that intelligence examinations are superior to subject-matter examinations for prediction of general academic success but inferior for prediction of attainment in specific subjects.

The Iowa Series of Placement Examinations appeared to be among the most highly successful of such examinations for the prediction of success in specific subjects.

The function of the placement examination and its need in the physics classes at the Missouri School of Mines were pointed out.

An objective subject-matter examination in physics was constructed and administered to more than five hundred students distributed among several schools. The results were carefully studied. From this study the following conclusions are drawn:

1. A range of scores is obtained which is

sufficiently broad to make the examination selective. It facilitates division of a large class into sections of differing abilities.

2. The reliability and validity of the examination are quite satisfactory. The reliability compares favorably with the reliabilities of the various Iowa Examinations.

3. The correlation of the scores made on the examination with subsequent achievement in physics compares favorably with such correlations for similar examinations.

4. The examination is at least equal in performance with other examinations available for the purpose for which it was designed.

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APPENDIX A

In this appendix are included two tables which were deemed too long for inclusion in the text.

Table 27

Correct Answers Given for Each Test Item by

Two Groups of Missouri School of Mines Students

(See text above, page 48)

Test part	Test item	No. of correct answers		Per cent of correct answers	
		No H.S. physics	H.S. physics	No H.S. physics	H.S. physics
One	1	30	88	88.2	91.5
	2	27	81	79.4	84.2
	3	17	60	50.0	62.4
	4	25	85	73.5	88.4
	5	19	60	55.9	62.4
	6	1	3	neg.	3.2
	7	11	39	32.2	42.8
	8	25	77	73.5	80.0
	9	31	87	91.2	90.8
	10	16	48	47.1	50.0
	11	13	43	38.2	44.7
	12	26	79	76.4	82.2
	13	26	72	76.4	74.9
	14	32	95	94.1	98.8
	15	27	76	79.4	79.0
	16	24	74	70.6	76.9
	17	6	10	17.7	10.4
	18	13	33	38.1	34.2
	19	6	10	17.7	10.4
	20	14	55	41.2	57.2
	21	20	51	58.8	53.1
	22	28	67	82.3	69.7
	23	21	62	61.7	64.5
	24	12	39	35.3	40.6
	25	25	73	73.5	85.9
	26	13	47	38.2	48.9
	27	12	46	35.3	47.8

Table 27, continued

Test part	Test item	No. of correct answers		per cent of correct answers	
		No H.S. physics	H.S. physics	No H.S. physics	H.S. physics
One	28	24	71	70.6	73.8
	29	14	56	41.2	58.2
	30	28	75	82.3	78.2
Two	1	23	83	67.5	86.4
	2	32	91	94.0	94.7
	3	21	81	61.7	84.3
	4	23	79	67.5	82.1
	5	30	95	88.2	98.8
	6	21	78	61.7	81.2
	7	15	38	44.1	39.5
	8	6	56	17.6	58.3
	9	29	90	85.2	93.8
	10	19	77	55.8	79.9
	11	17	60	50.0	62.4
	12	6	34	17.6	35.3
	13	17	67	50.0	69.7
	14	6	69	17.6	71.7
	15	17	69	50.0	71.7
	16	2	13	5.9	13.5
	17	7	62	12.5	64.5
	18	6	30	17.6	31.2
	19	21	76	61.6	79.1
	20	5	46	14.7	47.8
	21	20	86	58.8	89.5
	22	8	49	23.4	51.0
	23	31	91	91.2	94.7
	24	0	9	0	9.4
	25	5	20	14.7	20.8
	26	29	88	85.2	91.5
	27	22	74	64.6	77.2
	28	4	26	11.7	27.1
	29	28	88	82.2	91.5
	30	15	69	44.1	71.7
	31	7	52	20.5	54.1
	32	12	42	35.2	43.7
	33	9	66	26.4	68.6
	34	19	66	55.8	68.6
Three	1	23	85	67,8	88.4
	2	34	93	100.0	96.7
	3	31	89	91.2	92.6

Table 27, continued

Test part	Test item	No. of correct answers		Per cent of correct answers	
		No H.S. physics	H.S. physics	No H.S. physics	H.S. physics
Three	4	32	94	94.1	97.7
	5	29	68	85.2	70.6
	6	27	75	79.3	78.1
	7	28	84	82.2	87.3
	8	31	88	91.2	91.5
	9	15	65	44.1	67.6
	10	29	94	85.2	97.7
	11	30	82	88.2	85.1
	12	23	78	67.8	81.2
	13	34	96	100.0	100,0
	14	31	87	91.2	90.6
	15	32	87	94.1	90.6
	16	34	96	100.0	100.0
	17	27	82	79.3	85.1
	18	93	97	97.0	95.6
	19	26	92	76.3	95.6
	20	32	84	94.1	87.3
	21	29	88	85.2	91.5
	22	32	87	94.1	90.6
	23	31	86	91.2	89.5
	24	29	92	85.2	95.6
	25	30	91	88.2	94.7
	26	31	86	91.2	89.5
	27	27	82	79.3	85.1
	28	27	84	79.3	87.3
	29	26	89	76.3	92.6
	30	19	59	55.8	61.4
	31	29	80	85.2	83.2
	32	25	84	73.4	87.3
Four	1	23	87	67.6	90.6
	2	14	54	41.2	56.2
	3	10	79	29.4	82.1
	4	19	69	55.8	71.7
	5	23	84	67.6	87.3
	6	0	3	0	3.1
	7	7	31	20.5	32.2
	8	22	81	64.6	84.3
	9	10	36	29.4	37.4
	10	22	68	64.6	70.6
	11	23	77	67.6	79.9

Table 27, continued

Test part	Test item	No. of correct answers		Per cent of correct answers	
		No H.S. physics	H.S. physics	No H.S. physics	H.S. physics
Four	12	13	34	38.2	35.4
	13	23	58	67.6	60.3
	14	9	41	26.4	42.7
	15	8	29	23.4	30.1
	16	22	79	64.6	82.1
	17	22	74	64.6	77.2
	18	3	10	8.8	10.4
	19	6	55	17.6	57.3
	20	14	55	41.2	57.3
	21	8	57	23.4	59.5
	22	16	72	47.1	75.2
	23	4	20	11.7	20.9
	24	13	58	38.2	60.3
	25	10	38	29.4	39.5
	26	5	28	14.6	29.2
	27	11	22	32.3	22.9
	28	5	45	14.6	46.9
	29	8	43	23.8	44.8
	30	1	4	22.9	4.2

Table 28

Right, Wrong, and Omitted Answers Appearing

in a Group of 130 Papers Written by

Missouri School of Mines Students

(See page 55)

Part	Item	Right	Wrong	Omitted
One	1	118	11	1
	2	108	19	3
	3	77	38	15
	4	110	14	6
	5	79	35	15
	6	4	98	28
	7	50	58	22

Table 28, continued

Part	Item	Right	Wrong	Omitted
One	8	102	19	9
	9	118	7	5
	10	64	47	19
	11	56	67	7
	12	105	23	2
	13	98	30	2
	14	127	3	0
	15	103	22	5
	16	98	9	23
	17	24	31	75
	18	46	31	53
	19	16	74	40
	20	69	8	53
	21	71	29	30
	22	73	19	38
	23	83	17	30
	24	51	46	33
	25	98	19	13
	26	60	41	29
	27	58	50	22
	28	95	7	28
	29	70	18	42
	30	103	3	25
Two	1	106	7	17
	2	123	2	5
	3	102	18	10
	4	102	8	20
	5	125	0	5
	6	99	16	15
	7	53	30	47
	8	62	9	59
	9	119	3	8
	10	96	6	28
	11	77	19	34
	12	40	33	57
	13	84	25	21
	14	75	23	32
	15	86	2	42
	16	15	10	105
	17	69	22	39
	18	36	29	65
	19	97	15	18
	20	51	29	50
	21	106	8	16

Table 28, continued

Part	Item	Right	Wrong	Omitted
Two	22	57	17	56
	23	122	1	7
	24	9	12	109
	25	25	22	83
	26	117	8	5
	27	96	6	28
	28	30	15	85
	29	116	9	5
	30	84	25	21
	31	59	21	50
	32	54	10	66
	33	35	7	48
	34	85	0	45
Three	1	108	9	13
	2	127	2	1
	3	120	7	3
	4	126	2	2
	5	97	31	2
	6	102	19	9
	7	112	10	8
	8	119	9	2
	9	80	32	18
	10	123	0	7
	11	112	12	6
	12	101	12	17
	13	130	0	0
	14	118	12	0
	15	119	11	0
	16	130	0	0
	17	109	12	9
	18	125	5	0
	19	118	9	3
	20	116	12	2
	21	117	13	0
	22	119	10	1
	23	117	10	3
	24	121	2	7
	25	131	3	6
	26	117	5	8
	27	109	11	10
	28	111	5	14
	29	115	4	11
	30	78	31	21
	31	109	4	17
	32	104	11	15

Table 28, continued

Part	Item	Right	Wrong	Omitted
Four	1	110	18	2
	2	68	59	3
	3	89	41	0
	4	88	31	11
	5	107	21	2
	6	3	37	90
	7	38	45	47
	8	103	27	0
	9	46	81	3
	10	90	33	7
	11	100	30	0
	12	47	57	26
	13	81	41	8
	14	50	28	52
	15	37	86	7
	16	101	17	12
	17	96	27	7
	18	13	54	63
	19	61	39	30
	20	69	41	20
	21	65	34	31
	22	88	37	5
	23	24	27	29
	24	71	46	13
	25	48	50	32
	26	33	27	70
	27	55	15	60
	28	50	33	47
	29	51	13	66
	30	10	50	70

APPENDIX B

Glossary of Terms Used

Norms. Composite scores for comparative purposes.

Mean. The average of a group of scores. The sum of the separate scores divided by the number of separate scores.

Median. The middle score, or the score above which are one fourth of the scores.

Upper Quartile (Q_3). The score ~~above~~ below which are three fourths of the scores.

Lower Quartile (Q_1). The score below which are one fourth of the scores.

Percentile. The p percentile is the score below which are p of the scores. The median is the fiftieth percentile; the quartiles are the twenty-fifth and seventy-fifth.

Quartile deviation (Q). One half of the distance between Q_1 and Q_3 for a given distribution.

Average deviation (A.D.). The average of the deviations of all the measures in a series from their mean. A.D. is always larger than Q.

Standard deviation (S.D. or σ). The square root of the average squared deviations of the respective measures of a series from their arithmetical mean. S.D. is always larger than A.D.

Coefficient of correlation. An index figure stating the degree of relationship between two sets of data.

Placement examination. A test used as a criterion for dividing a class into sections.

Prognostic test. A test which attempts to predict subsequent success in a given subject.

APPENDIX C

The Correlation Coefficient and Its Calculation

The coefficient of correlation is an index figure summarizing the relationship between two measurements of the same group of individuals in much the same way that an arithmetic mean summarizes a distribution of scores. It gives in a single two- or three-place decimal number the amount of relationship existing between two more or less lengthy series of marks involving two different variables.

The formula commonly used for finding the correlation coefficient, designated by r, is

$$r = \frac{\Sigma xy}{\sqrt{\Sigma x^2 \Sigma y^2}}$$

where the x's and y's are the deviations of the measures in the series from their averages and Σ is a sign of summation. This formula is commonly known as the Pearson ''product moment'' formula. There are several variants which yield the same arithmetical value for r, and various charts and diagrams have been devised to simplify the calculations.

The correlation coefficients given in this study were calculated by use of the Otis Correlation Chart prepared by Arthur S. Otis and distributed by the World

Book Company. The formula upon which this chart is based is

$$r = \frac{\Sigma X^2 + \Sigma Y^2 - \Sigma V^2 - 2\Sigma X\Sigma Y \div N}{\sqrt{[\Sigma X^2 - (\Sigma X)^2 \div N][\Sigma Y^2 - (\Sigma Y)^2 \div N]}}$$

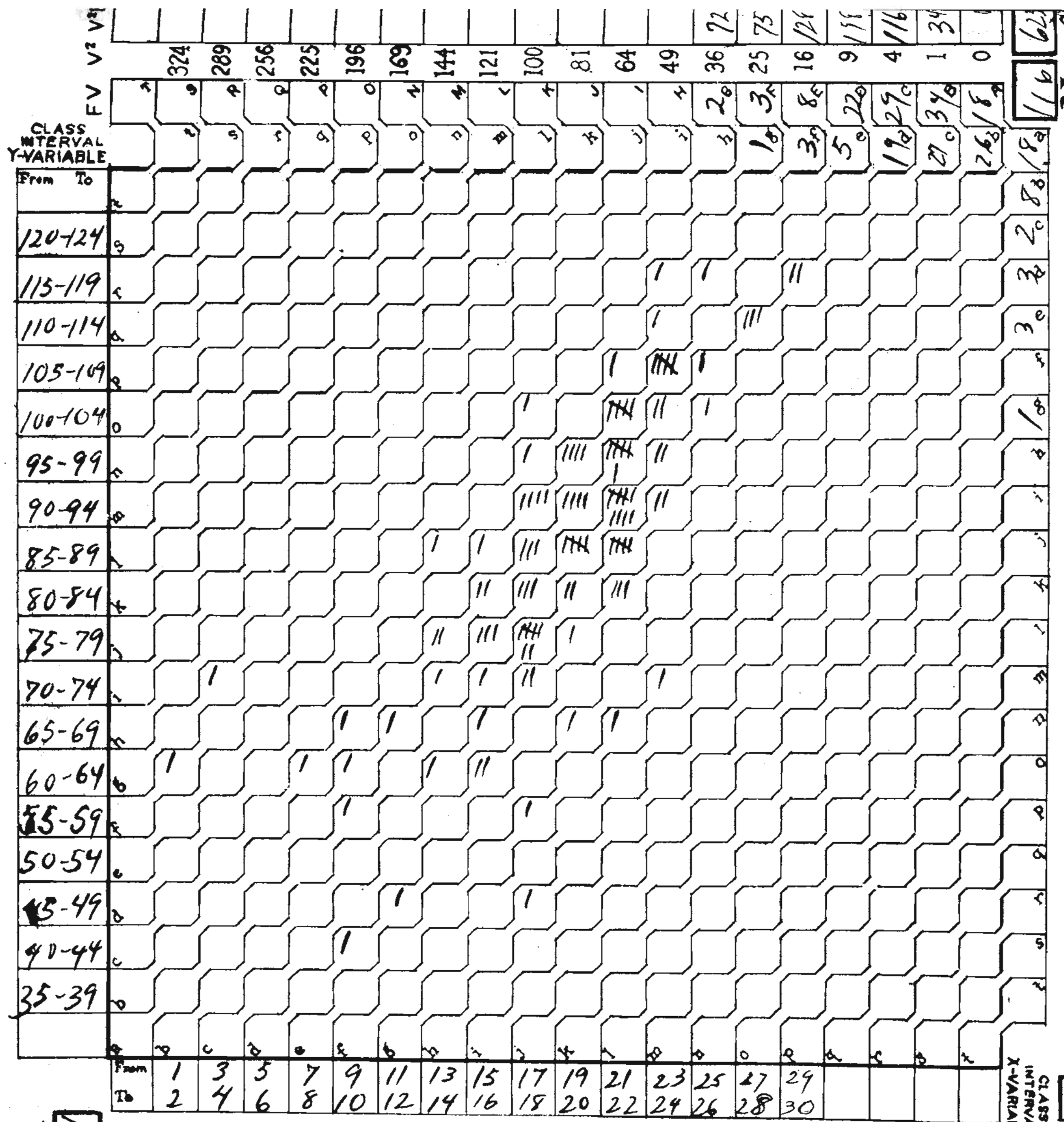
in which Y and X are measures on the two scales, and V = Y - X. The three, X, Y, and V, are measured from arbitrary zero points. This is the same formula as

$$r = \frac{\Sigma x^2 + \Sigma y^2 - \Sigma v^2}{2\sqrt{\Sigma x^2 \Sigma y^2}}$$

in which v = y - x, and in which x, y, and v are all measured from their true means.

Calculation of a coefficient by means of this chart is merely a matter of routine arithmetic after the frequencies of the scores are plotted. The procedure is well illustrated by the accompanying chart, Fig. 7, on which has been calculated the coefficient of correlation between the scores made by 116 Missouri University students and the scores made by the same students on Part Four of the examination. The process may be summarized briefly as follows. Suitable class intervals were chosen for the two score ranges and written in the proper places. A point was plotted on the diagram for each pair of scores, the horizontal position being determined by the value of the Part Four score and the vertical position by the total relation between Part Four Scores (x) and Total Scores (IIIo. U.) (y)

r_{xy} = .783 ± .044



		8	7	6	5	4	3	2	1	0	1	2	3	4	5	6	7	8	9	10	11	
N	116		1	1		1	4	2	5	16	23	17	30	14	3	3	2					FX
B	38		7	6		4	12	4	5	250 A	23	34	90	56	15	18	14					XFX
		64	49	36	25	16	9	4	1		1	4	9	16	25	36	49	64	81	100	121	X²
C	1026		49	36		16	36	8	5	0	23	78	270	224	75	108	98					X²FX

Correlation Formula

$$r_{xy}=\frac{(C+F-G)-2HJ\div N}{2\sqrt{(C-H^2\div N)(F-J^2\div N)}}$$

FY	Y	YFY	Y²	Y²FY
	11		121	
	10		100	
4	9	36	81	324
4	8	32	64	256
7	7	49	49	343
9	6	54	36	324
13	5	65	25	325
19	4	76	16	304
15	3	45	9	135
10	2	20	4	80
13	1	13	1	13
6	0	350 D		0
5	1	5	1	5
6	2	12	4	24
2	3	6	9	18
	4		16	
2	5	10	25	50
1	6	6	36	36
	7		49	
	8		64	
N 116		E 39		F 2237

CALCULATION

A	250	
B	38	
A-B	212	H
D	390	
E	39	
D-E	351	J
H	212	
HJ	74412	
HJ÷N	6415	
2HJ÷N	1283	K

H²	44944	
C	1626	
H²÷N	387	
C-H²÷N	639	P

J²	123201	
F	2237	
J²÷N	1062	
F-J²÷N	1175	Q

C	1026	
F	2237	
C+F	3263	
G	623	
C+F-G	2640	L
K	1283	
L-K	1357	M
	NUMERATOR	

PQ	750825	
√PQ	866	
2√PQ	1732	S
	DENOMINATOR	

M÷S	.783	r_{xy}
	COEF. OF COR.	

To find PE.r

r²	.713	
1- r²	.287	T
√N	10.77	W
T÷W	.0662	Z
.67Z	.044	P.E.r

To find σ_x

P÷N		a
√a		b
C.I.$_x$		c
bxc		
	σ_x	

To find σ_y

Q÷N		d
√d		e
C.I.$_y$		f
exf		
	σ_u	

To find M_x

d HC.I.$_x$		g
e g÷N		h
f M.V.$_x$		i
i+h		
	M_x	

To find M_y

g JC.I.$_y$		k
h k÷N		m
i M.V.$_y$		n
n+m		
	M_y	

score. The X-, Y-, and V-frequencies were determined by counting the tallies in the respective vertical, horizontal, and diagonal columns. The various parts of the general formula were calculated according to the instructions clearly given on the chart itself. The order of computations is indicated on the chart by alphabetical designations, A, B, C, etc.

The magnitude which a given coefficient of correlation must have in order to be significant depends to some extent upon the use to which it is to be put. The following summary, taken from <u>Measurements in Secondary Education</u>, by P. G. Symonds, will give a general idea of the value which a coefficient must have to be useful.

r = 0.90 the correlation of form A with form B of a forty-minute intelligence test in high school.

r = 0.80 the correlation of form A with form B of a forty-minute achievement test in high school.

r = 0.70 the correlation of first-semester marks of the same class and same teacher in a school that has a fairly good system of marking.

r = 0.60 the correlation of an average of elementary school marks with an average of first-year high school marks.

r = 0.50 the correlation of marks in one academic subject in high school with marks in another academic subject.

r = 0.40 the correlation of marks in an academic subject with marks on an intelligence test.

Another indication is given by Rugg (6, page 256), who says,

> "The experience of the present writer in examining many correlation tables has led him to regard correlation as "negligible" or "indifferent" when r is less than .15 to .20; as being "present but low" when r ranges from .15 or .20 to .35 or .40; as being "markedly present" or "marked" when r ranges from .35 or .40 to .50 or .60; as being "high" when it is above .60 or .70. With the present limitations on educational testing few correlations in testing will run above .70, and it is safe to regard this as a very high coefficient."

SUBJECT INDEX

AUTHOR INDEX

Paper No. _____ Section No. ____

A
PLACEMENT EXAMINATION
IN
GENERAL PHYSICS

Student's name: ______________________________ Sex: ____ Age: ____
(Surname) (Initials)

High School attended: ____________________ City: ___________ State:

Have you had a course in physics in high school? ______________

Test administered at ____________________________ on ____________
(School) (Date)

SCORING DATA

Allowable time. 50 minutes. Maximum possible score: 126

Division of time:

Cover page....... 1 minute.
Part 1...........14 "
Part 2........... 8 "
Part 3...........15 "
Part 4...........10 "
Transitions...... 2 "

Student's score:

	Right	Wrong	Omit	Score
Part 1				
Part 2				
Part 3				
Part 4				
Totals				

Acknowledgment: The selections used in Part 3 were chosen from Anderson's PHYSICS FOR TECHNICAL STUDENTS, published by McGraw-Hill Book Company. Used by permission.

PART ONE

DIRECTIONS: Place the answer to each question on the corresponding dotted line at the right. Use blank spaces on the page for necessary figuring. You have 14 minutes for Part One.

SAMPLE: $2x = 6$. What does x equal? 3

1. $W = Fd$. Solve for d. 1.________
2. What is one eighth of seven? 2.________
3. $S = \frac{1}{2}at^2$. Solve for t. 3.________
4. $a^3 = 8$. Express a without using radicals. 4.________
5. R is less than S. $R + S = S + 6$. Does R equal 6? 5.________
6. Express in symbols: m is proportional to the cube of d. 6.________
7. $\frac{1}{2}mv^2 = mgh$. Simplify and solve for v. 7.________
8. If $\frac{x + 1}{a} = \frac{y + 2}{a}$, is x larger or smaller than y? 8.________
9. Express in symbols: P_1 is to P_2 as V_2 is to V_1 9.________
10. Add: $\frac{1}{x} + \frac{1}{y}$. 10.________
11. x^2 is less than y. Can x be greater than y? 11.________
12. Which expression is imaginary: $\sqrt{a}$, $-\sqrt{a}$, $\sqrt{1}$, $\sqrt{-2b}$? 12.________
13. Multiply 2.5 x 2 by 3 x 0. 13.________
14. What is one-half of one-fourth? 14.________
15. $m = eit$. Solve for e. 15.________
16. What is the reciprocal of $\frac{2x}{a}$? 16.________
17. Solve (to one decimal place): $120\left(\frac{273}{330}\right)\left(\frac{770}{760}\right)$. 17.________
18. What is the mean of 1, 4, 0, 5, 5? 18.________
19. A is less than B. Is the mean of A and B less than B? 19.________
20. $F = 4\pi^2n^2rm$. Solve for r. 20.________
21. Write with an exponent: $\sqrt{x - y}$. 21.________
22. Add the next <u>two</u> terms to the series: 160, 80, 40, 20. 22.________
23. The reciprocal of a number is a. What is the number? 23.________
24. $c^2 + 1 = 0$. What is the value of c? 24.________
25. What does $\frac{0}{5}$ equal? 25.________
26. What is the cube of $4xy^2$? 26.________
27. What does $\frac{5}{0}$ equal? 27.________
28. $I = \frac{E}{R}$. If I is 10 and E is 220, what is the value of R? 28.________
29. By how much does B exceed A if $A = B - C$? 29.________
30. Write as a decimal fraction: 3/4 30.________

Maximum Score: 30	Character of responses Right: Wrong: Omit:	How scored: Number right	Score:

PART TWO

DIRECTIONS: Below are sketches and diagrams representing various physical devices or principles used in engineering practice. Each sketch is numbered. To the right is a list of the principles or devices illustrated. On the blank preceding the name write the number of the sketch illustrating it. You will find it helpful to cross out each sketch as it is identified. You have 8 minutes for Part Two.

SAMPLE: Sketch 12 is a simple pendulum. Hence, place the number 12 on the blank before the name, as shown to the right.

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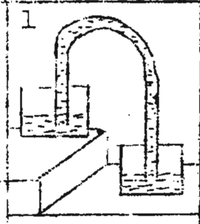

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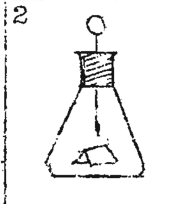

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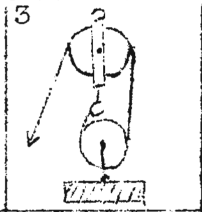

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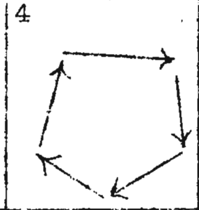

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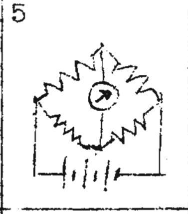

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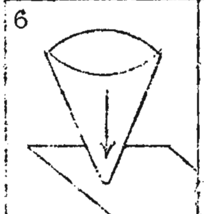

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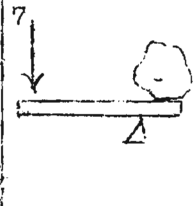

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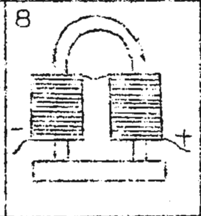

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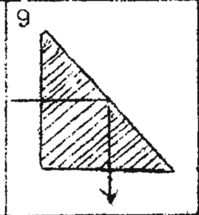

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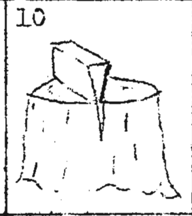

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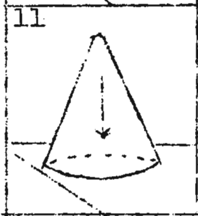

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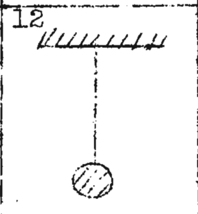

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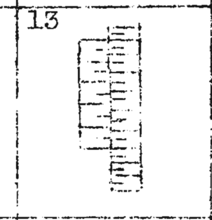

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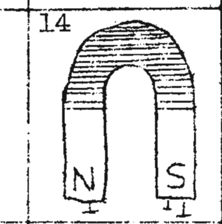

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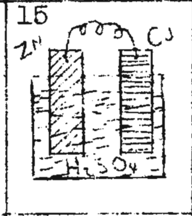

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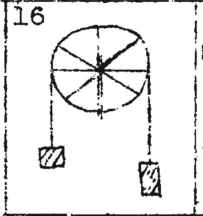

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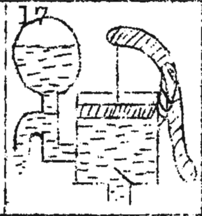

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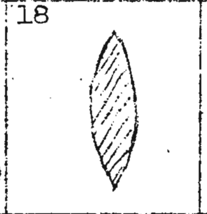

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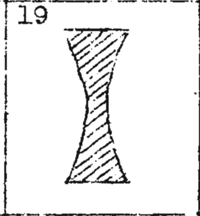

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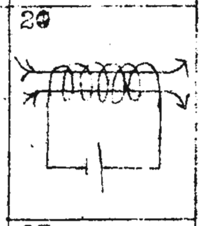

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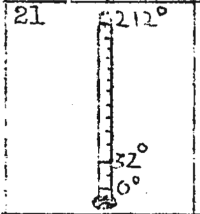

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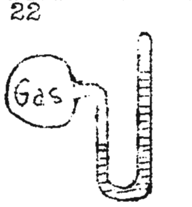

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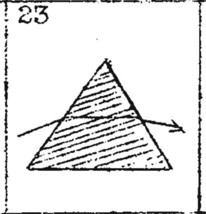

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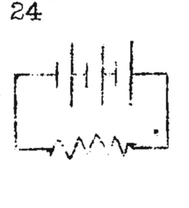

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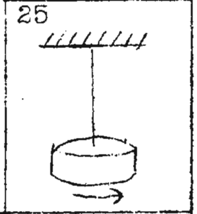

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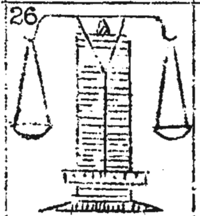

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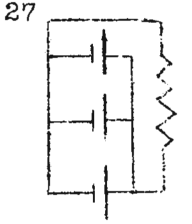

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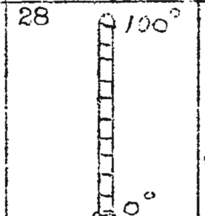

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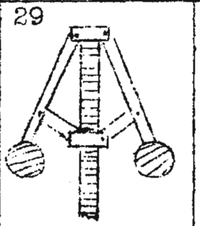

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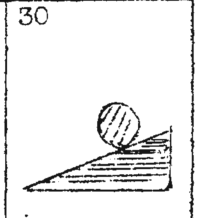

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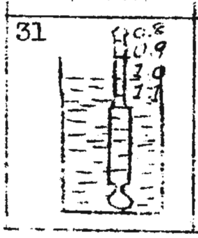

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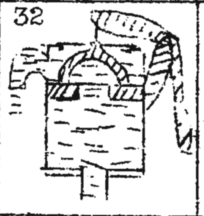

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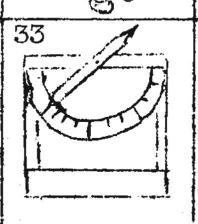

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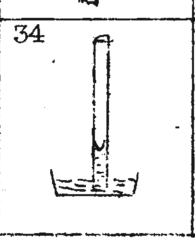

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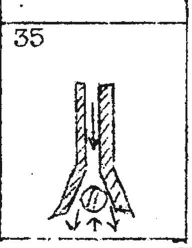


No.		Name
	12	Simple pendulum
1	____	Lever
2	____	Block and tackle
3	____	Electromagnet
4	____	Beam balance
5	____	Siphon
6	____	Double convex lens
7	____	Torsion pendulum
8	____	Electroscope
9	____	Permanent magnet
10	____	Voltaic cell
11	____	Vernier
12	____	Stable equilibrum
13	____	Lift pump
14	____	Refracting prism
15	____	Centrifugal governor
16	____	Solenoid
17	____	Reflecting prism
18	____	Unstable equilibrum
19	____	Double concave lens
20	____	Cells in series
21	____	Inclined plane
22	____	Force diagram
23	____	Wedge
24	____	Atwood's machine
25	____	Manometer gauge
26	____	Centigrade thermometer
27	____	Hydrometer
28	____	Wheatstone bridge
29	____	Fahrenheit thermometer
30	____	Force pump
31	____	Cells in parallel
32	____	Dipping needle
33	____	Capillary column
34	____	Ball nozzle

Maximum Score: 34	Character of responses Right: Wrong: Omit:	How scored: Number right	Score:

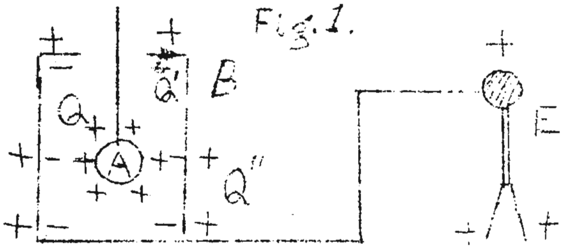
PART THREE

DIRECTIONS: This section consists of selections from a standard college text in physics. To the right are a number of statements which may or may not be true. Read each selection and compare the statements with the material in the selection. If the statement is true, place a T on the dotted line following it; if false, place an F on the dotted line. DO NOT GUESS. Part Three contains two pages; go on to the second without interruption. You have 15 minutes for Part Three.

. . . .

1. FARADAY'S ICE-PAIL EXPERIMENT.

The experiment received this name because Faraday happened to use an ice-pail in performing the experiment the first time. Any hollow conductor, such as B (Fig. 1), would have answered equally as well. E is a gold-leaf electroscope connected to B by a wire. In the top of B is an opening large enough to admit the charged body A. If A is positively charged, then, as it is brought near the uncharged, insulated vessel B, electrical separation takes place, the negative being attracted and the positive repelled. A small part of the repelled positive charge passes to the electroscope and causes the leaves to separate. As soon as A is well in the vessel B, the leaves cease to separate farther, and simply remain stationary as A is moved about within B.



It will now be shown that the charge +Q on A, the induced charge -Q' on the inside of B, and the induced charge +Q" on the outside of B are all equal. That the charges Q' and Q" are equal (disregarding sign) is shown by the fact that, if A is withdrawn without coming in contact with B, the gold leaves collapse, for, if Q' were (say) -10 and Q" were +11, there would be one + unit not neutralized, and the leaves would still diverge slightly. If, on the other hand, A is lowered until it touches the bottom of B, the leaves neither rise nor fall. This fact shows that Q equals Q', numerically, since they just neutralize each other and leave Q" unchanged.

1. Any deep hollow conductor with a small opening may be used in this experiment. ______
2. The materials for this experiment must be cooled by ice. ______
3. As discussed, the body A carries a positive charge. ______
4. An electroscope is indicated by E in the diagram. ______
5. If A is moved about in B, the leaves of the electroscope remain stationary. ______
6. The induced charge on the inside of the pail is equal to the charge on A(neglecting sign). ______
7. The induced charge on the outside of the pail is greater than that on the inside of the pail (neglecting sign). ______
8. If A is withdrawn without touching B, the leaves of the electroscope collapse. ______
9. Collapse of the leaves proves that the charge has been lost. ______
10. The leaves of this electroscope are made of aluminum. ______
11. If A is lowered to touch the bottom of B, the leaves of the electroscope collapse. ______
12. Negative charges are attracted by A, while positive charges are repelled. ______

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SECOND PAGE, PART THREE

2. The energy of a body may be defined as the ability of a body to do work. The potential energy of a body is its ability to do work by virtue of its position or condition. The kinetic energy of a body is its ability to do work by virtue of its motion. Energy may be transformed from potential to kinetic energy and vice versa, or from kinetic energy into heat, or by a suitable heat engine, e.g., the steam engine, from heat into kinetic energy, but whatever transformation is experienced, in a technical sense, none is lost. In practice, energy is lost, as far as useful work is concerned, in the operation of all machines, through friction of bearings, etc. This energy is spent in overcoming friction. It is not actually lost, but is transformed into heat energy which cannot be profitably reconverted into mechanical energy. In all cases of energy transformations, the energy in the new form is exactly equal in magnitude to the energy in the old form. This fact, that energy can neither be created nor destroyed, is referred to as the law of the Conservation of Energy.

1. Energy of a body is the ability of the body to do work. ______
2. A body has only one kind of energy. ______
3. Kinetic energy is ability to do work by virtue of position. ______
4. Energy may be transformed from potential into kinetic energy. ______
5. Heat converts energy into friction. ______
6. A steam engine converts heat into kinetic energy. ______
7. The amount of energy in existence is constant. ______
8. Energy used in overcoming friction is destroyed. ______
9. Potential energy is the ability to do work by virtue of motion. ______
10. The magnitude of energy after transformation is less than the magnitude before transformation. ______

3. <u>The electron theory</u>. According to this theory, now generally accepted, electricity is corpuscular in its nature. Indeed, it may be said that electricity consists of negatively charged particles, the electrons, each of which has a mass about 1/1845 that of the hydrogen atom. Streams of these electrons constitute the β-rays (beta rays) emitted by radioactive substances, and they also constitute the cathode rays which give rise to the x-rays. The γ-rays (gamma rays) which accompany β-rays, and also the x-rays, are radiations of exceedingly short wave length. The electrons, as they rapidly revolve about the atoms, are also considered to be the ultimate source of the ether vibrations in radiation. According to the electron theory, an excess of electrons upon a body causes the body to be negatively charged; a deficiency, positively charged. An uncharged or neutral body has its normal supply of electrons. It is of interest to know that the charge on the electron has been measured and that unit negative charge is equal to 2.1 x 10^9 electrons.

1. According to the electron theory, electricity consists of negatively charged particles. ______
2. A negative electric charge results when a body has an excess of electrons. ______
3. The charge on an electron has been measured. ______
4. Streams of electrons known as cathode rays are the cause of x-rays. ______
5. An uncharged body lacks some electrons. ______
6. Electricity is generally accepted to be corpuscular in nature. ______
7. The electron is larger than the hydrogen atom. ______
8. Electrons are caused by ether vibrations. ______
9. Electrons revolve rapidly around the atoms. ______
10. A positively charged body has the normal number of electrons. ______

Maximum Score: 32	Character of responses right: wrong: omit:
How scored: Number right	Score:

PART FOUR

DIRECTIONS: Read each question and select the best answer from the five given. Place the number of this answer on the line at the right, as shown in the sample. This part consists of two pages; go on to the second without interruption. You have 10 minutes for Part Four.

SAMPLES: 1. A mile is most nearly (1) 1000 yards, (2) 2000 yards, (3) 3000 yards, (4) 4000 yards, (5) 5000 yards. 2

2. The unit for measuring electrical resistance is (1) ampere, (2) watt, (3) volt, (4) erg, (5) ohm. 5

. . . . . .

1. The measure nearest the yard in length is the (1) millimeter, (2) centimeter, (3) meter, (4) foot, (5) rod. ______

2. A common unit of mass is the (1) liter, (2) cubic foot, (3) centimeter, (4) gram, (5) erg. ______

3. Three forces acting at an angle may be replaced by a single force producing the same effect. This force is called a (1) component, (2) equilibrant, (3) resultant, (4) diagonal, (5) force polygon. ______

4. Light which passes through an ordinary prism is (1) polarized, (2) diffused, (3) refracted, (4) reflected, (5) absorbed. ______

5. The freezing point on the Centigrade thermometer is (1) 0°, (2) 212°, (3) 100°, (4) -273°, (5) 32°. ______

6. A device involving Bernoulli's principle is the (1) siphon, (2) hygrometer, (3) electrophorus, (4) interferometer, (5) atomizer. ______

7. The quantity commonly indicated by "g" is the (1) acceleration of gravity, (2) gas constant, (3) ionization constant of gases, (4) universal gravitational constant, (5) temperature gradient. ______

8. An instrument often used to measure the density of liquids is a (1) hygrometer, (2) barometer, (3) anemometer, (4) hydrometer, (5) pedometer. ______

9. The velocity of a body may be expressed in (1) foot pounds, (2) dynes, (3) grams per second, (4) miles per hour, (5) feet per second per second. ______

10. The transfer of an electric current through a liquid is called (1) transmission, (2) conductance, (3) magnetism, (4) penetration, (5) permeability. ______

11. The quantity of heat in a body is measured in (1) degrees, (2) watts, (3) calories, (4) coulombs, (5) poundals. ______

12. An object is placed outside the center of curvature of a concave mirror. The image formed is (1) virtual, (2) upright, (3) larger than the object, (4) smaller than the object, (5) situated behind the mirror. ______

13. The ampere is the unit used for expressing (1) resistance, (2) electric current, (3) electrical conductance, (4) electromotive force, (5) potential gradient. ______

14. Vectors are distinguished from scalars by having (1) length, (2) magnitude, (3) mass, (4) direction, (5) force. ______

(Go on to the next page)

15. The time rate of change of position of a body is known as (1) force, (2) acceleration, (3) speed, (4) rotation, (5) displacement. ______

16. The kilometer corresponds most closely in length to the (1) foot, (2) yard, (3) rod, (4) mile, (5) inch. ______

17. Energy possessed by virtue of motion is called (1) potential, (2) latent, (3) free, (4) kinetic, (5) static. ______

18. Lines plotting relationship between pressure and volume are called (1) isotherms, (2) isobars, (3) components, (4) isoclinic lines, (5) critical lines. ______

19. Heat can pass through a vacuum only by (1) capillarity, (2) conduction, (3) convection, (4) radiation, (5) absorption. ______

20. The speed of sound in air is approximately (1) 1080 feet per second, (2) 186,000 miles per second, (3) 980 centimeters per second, (4) 32 feet per second, (5) 300,000 kilometers per second. ______

21. A man whose name is associated with falling bodies is (1) Watt, (2) Galileo, (3) Faraday, (4) Archimedes, (5) Copernicus. ______

22. Ice melts at (1) 30°F, (2) 30°C, (3) 212°F, (4) 32°F, (5) 32°C. ______

23. The stress commonly experienced by a rafter in a building is a (1) shear, (2) tension, (3) compression, (4) twist, (5) torque. ______

24. An instrument used to detect electric charges is the (1) spectroscope, (2) electroscope, (3) voltmeter, (4) dynamometer, (5) polariscope. ______

25. The quantity of heat liberated by unit mass of water upon freezing is called (1) specific heat, (2) mechanical equivalent of heat, (3) latent heat of fusion, (4) radiant heat, (5) latent heat of vaporization. ______

26. A manometer gauge measures (1) depth, (2) speed, (3) density, (4) pressure, (5) temperature. ______

27. A 150-lb. man climbs to a height of 20 feet in five seconds. The foot-pounds of work done are (1) 150, (2) 20, (3) 100, (4) 3000, (5) 750. ______

28. The time rate of change of speed of a body is called (1) force (2) momentum, (3) velocity, (4) acceleration, (5) force of restitution. ______

29. The acceleration of gravity in feet per second per second is approximately (1) 980, (2) 4.187, (3) 772, (4) 2.54, (5) 32. ______

30. The unit of electrical capacitance is called the (1) dyne, (2) coulomb, (3) ampere, (4) farad, (5) watt. ______

Maximum Score: 30	Character of responses Right: Wrong: Omit:	How scored: Number right	Score: