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This study was designed to ascertain the relative effectiveness of two approaches for teaching descriptive geometry by a comparison of the following behavioral variables--(1) performance in the solution of graphical problems, (2) spatial perception, (3) abstract reasoning ability, (4) technical information achievement, and (5) attitude toward descriptive geometry. The two teaching approaches employed were a directed problem analysis approach and a traditional approach. The design involved the pretesting of groups, application of treatments, and post-testing to ascertain the effects of the treatments. The results of the study indicated that student behavioral changes and the retention of selected elements of descriptive geometry were not significantly affected by the instructional approach. (RP)

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A COMPARISON OF TWO APPROACHES TO TEACHING SELECTED ELEMENTS OF COLLEGE LEVEL DESCRIPTIVE GEOMETRY

by

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CHAPTER I

ORIENTATION TO THE PROBLEM

With the accelerated rate at which technological, social, and educational changes are taking place, there is an increased emphasis being placed upon quality education and training. Increasingly, educators are being called upon to prepare individuals who possess the capabilities to compete successfully in today's complex technological society.

The vast explosion of knowledge in recent years has added a multitude of new courses to the school curriculum and caused the deletion or change of many others. As a result, a host of instructional problems have emerged. Prominent among these problems, and one which has been accorded sporadic consideration, is that of more effectively organizing educational experiences in an attempt to improve student ability to analyze and solve problems as well as to apply these problem solving techniques in practical situations.

In the technical realm, instruction in the fundamentals of descriptive geometry has been, and continues to be, a versatile tool which prospective engineers and technicians should learn to use effectively as an aid in the solution of a multiplicity of scientific and technical problems.[1] This science of graphic representation and solution of space problems is intended to assist the individual in analyzing and solving technical problems as well as improving his spatial perception. Educators involved in technical and engineering programs have long recognized the importance of analytical thinking and the visualization of spatial relationships as essential competencies possessed by the successful technical person. Persons who manage the industrial engineering functions in contemporary industry are exerting much pressure upon educators to provide technically competent individuals who are able to communicate graphically and effectively analyze and solve problems of a technical nature.[2]

Logically, teaching approaches should be grounded in sound principles of learning that have their foundations in the psychological laboratory and that have been

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[1]E. G. Pare, R. O. Loving, and I. L. Hill, Descriptive Geometry (second edition; New York: The Macmillan Company, 1959), p. 2.

[2]Anthony Lord, "Education Stretchouts and Open Ends," Engineering Graphics, 6:15, April, 1966.

experimentally investigated in the classroom. Carroll[3] emphasizes a need for additional information concerning the improvement of instruction through ". . . the study of how empirical laws of learning can be applied in the classroom situation." It is suggested that the problem lies in the organization of teaching procedures in such a way that full benefits of these laws of learning can be realized. The problem analysis approach to the graphical solution of technical problems is one such teaching procedure which needs to be extensively investigated in learning situations.

Guilford[4] suggests a logical relationship between problem solving and learning when he says, "Changes in behavior . . . that come about through efforts to cope with problems, and that endure for any appreciable length of time, are in the category of learning."

Numerous writers in the field of engineering graphics exhibit confidence in the analytical approach to solving problems in descriptive geometry. Hawk[5] contends that a

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[3] John B. Carroll, "Neglected Areas in Educational Research," Phi Delta Kappan, 42:339-43, May, 1961.

[4] J. P. Guilford, "Creative Thinking and Problem Solving," The Education Digest, 29:29-31, April, 1964.

[5] Minor Clyde Hawk, Theory and Problems of Descriptive Geometry (New York: Schaum Publishing Company, 1962), Preface.

thorough understanding of the fundamentals of graphical analysis in descriptive geometry is essential to the development of a student's potential for solving technical problems.

Rowe and McFarland[6] suggest that drill in the analysis of problems is an important contributing factor in the development of an individual's ability to think in space. A similar viewpoint is reflected by Slaby when he suggests that descriptive geometry should be studied with the idea that everything must be visualized in three-dimensional space. Slaby declares, ". . . the student should try to develop this ability by analyzing and giving reasons for each step he takes in the solution of problems."[7]

How to best assist individuals in the development of skill in solving technical problems through an analysis approach constitutes a continuous source of concern for teachers of descriptive geometry. Moreover, research involving the effectiveness of teaching methods and

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[6]Charles E. Rowe and James D. McFarland, Engineering Descriptive Geometry (third edition; New York: D. Van Nostrand Company, Inc., 1961), p. iv.

[7]Steve M. Slaby, Engineering Descriptive Geometry (New York: Barnes and Noble, Inc., 1963), p. v.

approaches in descriptive geometry is sorely lacking. Consequently, teaching approaches which attempt to develop problem analysis techniques need to be identified, compared, and evaluated in terms of their relative effectiveness.

Statement of the Problem

Various approaches to the improvement of instruction in drafting have been attempted by instructors and researchers in the field. The use of teaching devices and approaches, such as models and mock-ups, overhead projection transparencies, films, film slides, filmstrips, and programed materials are much in evidence in the modern drafting classroom.

However, due to the abstract nature of the space relationships of lines, points, planes, and surfaces encountered in descriptive geometry, the challenge of obtaining maximum learning efficiency from classroom and laboratory procedures continues to confront the profession. The task of ascertaining the more effective means of assisting students in the development of their ability to analyze and solve problems of a technical nature constitutes a problem of paramount importance to teachers of descriptive geometry.

Well-known writers in the field advocate the extensive use of problem analysis techniques as excellent modes of instruction. However, there is currently a lack of adequate experimental evidence regarding the effectiveness of problem analysis techniques which clearly substantiate or refute these points of view.

Purpose of the Study

The purpose of this study was to ascertain whether or not students who had received instruction in descriptive geometry by a directed problem analysis approach were able to attain significantly greater levels of competence than students who had received instruction by a more conventional approach. A more complete description of these approaches is provided in Chapter III.

More specifically, the study sought answers to the following questions:

1. Do the instructional approaches significantly affect student performance in the solution of graphical problems in descriptive geometry?

2. Do the instructional approaches significantly affect student ability to visualize spatial relationships?

3. Do the instructional approaches significantly affect student ability to reason abstractly?

4. Do the instructional approaches significantly affect student achievement relative to technical information in descriptive geometry?

5. Do the instructional approaches significantly affect student attitude toward the course?

Definition of Terms

Descriptive geometry is a graphical method of solving space or solid analytic geometry problems relating to points, lines, planes, surfaces, intersections, and developed surfaces.[8]

Engineering graphics is the combination of those arts and sciences of drawing applicable to the solution of engineering problems.[9]

Graphic problems, as used in this study, refers to graphic performance tasks (primarily accurate drawings) to be completed by students in the drafting laboratory. These tasks provide opportunity for the application of fundamental principles and concepts of descriptive geometry in addition to logical reasoning as presented in class lectures, textbooks, and supplementary reference materials.

Spatial perception refers to the capacity to visualize the relationship of lines, points, planes, and objects to one another as they occupy positions in space.

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[8]Steve M. Slaby, Fundamentals of Three-Dimensional Descriptive Geometry (New York: Harcourt, Brace and World, Inc., 1966), p. vii.

[9]James S. Rising and Maurice W. Almfeldt, Engineering Graphics (third edition; Dubuque, Iowa: William C. Brown Book Company, 1964), p. 1.

Abstract reasoning refers to the act or process of arriving at conclusions through the use of symbols or generalizations rather than concrete data, as in dealing with geometric lines and shapes.[10]

Technical information refers to information in the area of descriptive geometry principles, techniques and terminology. This variable is commonly measured by means of objective-type examinations.

Attitude refers to student empathy or reaction to this course as revealed by responses on an attitude scale.

Directed problem analysis (Approach A) refers to a form of laboratory procedure whereby the student is required to identify, separate, and order, in written form, the constituent elements or factors inherent in the problem under consideration prior to attempting an accurate solution. Complete or partial illustrative sketches of tentative solutions may be used by the student to supplement this procedure. In this approach, the student will progress from group lecture to a written analysis of each problem which is applied to a final accurate drawing representing a solution to the assigned problems.

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[10]Carter V. Good (ed.), Dictionary of Education (New York: McGraw-Hill Book Company, Inc., 1959), p. 447.

Conventional approach (Approach B) refers to a form of laboratory procedure whereby the student attempts an accurate solution to the problem under consideration without the aid of a preliminary, structured, written or graphical analysis of the problem. In this approach, the student progresses from group lecture directly to an attempted final and accurate graphical solution of assigned problems.

On the basis of communication with instructors of descriptive geometry and a review of pertinent literature, it is assumed that this is one of the most frequently applied instructional approaches.

Retention is defined as the degree to which students are able to analyze and provide graphical solutions for problems relating to the spatial relationship of lines, points, and planes as well as their capacity to respond to items involving related technical information three weeks after treatment.

Hypotheses

The research hypotheses under consideration in this study were: (1) that selected elements of descriptive geometry could be taught more effectively, in terms of student behavioral changes, by the directed problem analysis approach, and (2) that the retention of selected elements of descriptive geometry would be superior for students experiencing the directed problem analysis approach than for those experiencing a traditional approach.

The first research hypothesis was tested by accepting or rejecting the following null hypotheses:

Ho_1: No significant difference exists between the graphic problem solving ability of students who experience the directed problem analysis approach and the graphic problem solving ability of students who experience the conventional approach.

Ho_2: No significant difference exists between the spatial perception of students who experience the directed problem analysis approach and the spatial perception of students who experience the conventional approach.

Ho_3: No significant difference exists between the abstract reasoning ability of students who experience the directed problem analysis approach and the abstract reasoning ability of students who experience the conventional approach.

Ho_4: No significant difference exists between the informational achievement of students who experience the directed problem analysis approach and the informational achievement of students who experience the conventional approach.

Ho_5: No significant difference exists between the attitude toward the course of students who experience the directed problem analysis approach and the attitude toward the course of students who experience the conventional approach.

The second research hypothesis was tested by accepting or rejecting the following null hypotheses:

Ho_6: No significant difference exists between the retention, in terms of graphic problem solving ability, of students who experience the directed problem analysis approach and the retention of students who experience the conventional approach as measured three weeks after treatment.

Ho_7: No significant difference exists between the retention of cognitive content of students who experience the directed problem analysis approach and the retention of students who experience the conventional approach as measured three weeks after treatment.

Scope and Limitations of the Study

This study was an attempt to ascertain the relative effectiveness of two approaches to teaching selected elements of descriptive geometry. The following variables were the basis upon which criterion measures of effectiveness were developed: (1) student competency in solving graphic problems, (2) student ability to visualize spatial relationships, (3) student ability to reason abstractly, (4) student informational achievement, and (5) student attitude toward the course. In a further attempt to assess effectiveness, measures of retention related to student competency in providing graphical solutions to problems relating to the spatial relationship of lines, points, and planes and informational achievement, were secured for students experiencing the two different instructional approaches. Measures of relative effectiveness of each approach, in terms of retention, were secured three weeks after the experimental period. The effectiveness of tests, lectures, and class discussion in which students participated was assumed to be equal for each of the classes involved in the investigation.

The study was limited to fifty-two students enrolled in two sections of ME 10 Descriptive Geometry, a course in the Department of Mechanical Engineering in the College of Engineering located on the campus of the University of Missouri - Columbia. The persons involved in the experiment were engineering students majoring in one of the several engineering departments of the College of Engineering.

All students were enrolled during the fall semester of the 1967-1968 school year. The length of the experimental period was eight weeks.

The ability to generalize the findings of the study waslimited to the extent that students in both sections were comparable and representative of students enrolled in college level courses in descriptive geometry at the University of Missouri or other institutions of higher education. The study was further limited by the two instructional approaches chosen by the researcher and the selected content elements of descriptive geometry which were presented during the experiment.

Since the study involved several tests, it was limited to the extent that all students understood the test items and performed to the best of their ability. The validity and reliability of the measuring devices employed in the study were also limiting factors.

Finally, the study was limited to the extent that all independent variables were controlled or held constant for the groups exposed to each of the two instructional approaches.

Sources of Data and Method of Study

The study was conducted as a controlled experiment involving two groups of students enrolled in ME 10 Descriptive Geometry in the Department of Mechanical Engineering, University of Missouri - Columbia.

The population studied consisted of students who were enrolled in two sections of ME 10 Descriptive Geometry during the fall semester of the 1967-1968 school year. The researcher acted in a coordinating capacity during the course of the investigation, but was not directly involved in teaching either of the two treatment groups. Students registered for the course and were assigned to the sections according to the availability of space. The two instructional approaches to teaching descriptive geometry were randomly assigned to the sections. Both sections were accepted as assigned, and the researcher planned to statistically control any significant differences in initial status which might have existed through the analysis of covariance. However, since the groups were found to be equivalent initially, the covariance adjustment was not employed.

In experimental studies, it is necessary to ascertain the initial status of all groups for the variables to be controlled, thus allowing for the comparison of results. The factors which seemed most likely to affect the results of this study and which could be statistically controlled with some degree of success were: (1) scholastic aptitude, and (2) knowledge of drawing related to descriptive geometry.

Student scores on the Cooperative School and College Ability Test were used as the measure of scholastic aptitude. These scores were obtained from the records of the Testing and Counseling Service at the University of Missouri - Columbia.

The student's knowledge of drawing related to descriptive geometry was measured by administering Blum's Comprehensive General Drafting Examination[11] as a pretest. Other selected factors relative to age and number of semesters of college work completed by each student were analyzed to ascertain whether or not the two groups differed significantly. Additional pretests were administered for spatial relationships, abstract reasoning, and student attitude toward the course to aid in ascertaining the effect of the experimental treatment on these criterion variables.

The data were analyzed by using the t-test of uncorrelated means to ascertain whether or not significant differences existed initially between the two groups with regard to the above control and criterion variables.

An experienced instructor of descriptive geometry taught both sections and all students used the same textbook,[12] course outline,[13] schedules of assignments,[14]

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[11]See Appendix A.

[12]Frank M. Warner and Mathew McNeary, Applied Descriptive Geometry (fifth edition; New York: McGraw-Hill Book Company, Inc., 1959).

[13]See Appendix C.

[14]See Appendix C.

reading and graphic problem assignments, and covered the same instructional content.

Both sections met twice each week for sixteen weeks in one hundred and ten minute laboratory sessions with one additional fifty minute period per week devoted to group lecture. The experimental period for this study was limited to the first eight weeks of the 1967-1968 fall semester.

One unit examination and several quizzes were administered to each section as a part of the regular instructional program and records were kept on all testing. Records of scores on required laboratory assignments were also maintained.

A graphic problem performance test,[15] the space relations and abstract reasoning sections of the Differential Aptitude Tests, Form L,[16] a technical information test,[17] and Remmers' Scale for Measuring Attitude Toward Any School Subject,[18] were used to provide data for testing the first research hypothesis for the study.

A graphic problem performance test[19] which was similar, but not identical, to the posttest of performance

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[15]See Appendix B.

[16]See Appendix A.

[17]See Appendix B.

[18]See Appendix A.

[19]See Appendix B.

and the same test which was used as the posttest of informational achievement provided data for testing the second research hypothesis for the study. More information relative to the aforementioned tests is provided in Chapter III.

Appropriate variations of the t-test were employed in the analysis of the data. The five per cent level of confidence was used to ascertain whether or not the observed differences would be greater than those expected by chance alone.

Related Literature and Research

Numerous studies have been made in an attempt to assess the effectiveness of methods of teaching various subjects; however, relatively few have been directly concerned with descriptive geometry. Although there were no investigations that closely paralleled this study with which the researcher could compare his design, there were several articles and studies with sufficient relationship to the content and/or method of this study to be reported herein. The literature and research reported in this section are related to the following aspects of the study: (1) problem solving, (2) experiments in descriptive geometry, and (3) experiments in drafting.

Problem Solving. Due to the acceleration of scientific and technical knowledge, increased emphasis is being placed upon the means of acquiring knowledge rather than subject matter per se. Denton, writing in The High School Journal, suggested that the problem solving approach to learning and teaching could fulfill education's need for a theory because ". . . it places reliance upon individual judgement, encourages a scientific approach to problems, enhances creativity and, in short, helps to produce self-reliant individuals."[20]

In a demonstration conducted by Elmore[21] and others, both teachers and students emphasized the superiority of the problem solving approach in contrast to the text-and-lecture approach to the teaching of science.

A study conducted by Keil[22] at Indiana University attempted to test the null hypothesis that there was no

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[20]William H. Denton, "Problem-Solving as a Theory of Learning and Teaching," The High School Journal, 49:389, May, 1966.

[21]Clair W. Elmore, Oreon Keeslar, and Clyde E. Parrish, "Why Not Try the Problem Solving Approach?" The Science Teacher, 28:37, December, 1961.

[22]Gloria E. Keil, "Writing and Solving Original Problems as a Means of Improving Verbal Arithmetic Problem Solving Ability," (unpublished Doctor's dissertation, University of Indiana, Bloomington, 1964).

significant difference in problem solving ability between children who wrote and solved their own arithmetic problems and children who solved textbook problems. Data were obtained from test results of a population consisting of 226 sixth-grade pupils of eight schools in a large suburban community of a midwestern state.

Analysis of covariance was the statistical technique used. Final achievement in arithmetic was the criterion variable while intelligence quotient and initial achievement were the control variables.

From the findings the experimenter concluded that pupils who wrote and solved problems of their own were superior in arithmetic problem solving ability to those pupils who had the usual textbook experiences in mathematical problem solving.

The extent to which the way in which one learns a generalization affects the probability of his recognizing a chance to apply it, was the subject of a study in the field of mathematics by Hendrix.[23]

The study employed three methods of instruction: (1) the "tell-and-do" method with the generalization stated

[23] Gertrude Hendrix, "A New Clue to Transfer of Training," The Elementary School Journal, 48:198, September, 1947.

first then illustrated and then applied to new problems; (2) the "unverbalized awareness" method in which the students were asked to find the sum of the first two odd numbers, the sum of the first three odd numbers, etc.; and (3) the "conscious generalization" method which proceeded as the second, except that the students were asked to state the rule they had discovered.

From the findings Hendrix concluded that:

1. For generalization of transfer power the "unverbalized awareness" method of learning a generalization was better than a method in which an authoritative statement of the generalization comes first.

2. Verbalizing a generalization immediately after discovery does not increase transfer power.

3. Verbalizing a generalization immediately after discovery may actually decrease transfer power.[24]

In contrast, Maltzman, Eisman, and Brooks[25] found no differences when three variations of test reading, illustration demonstrations, and problem solving demonstration preceded the solving of a problem from physics.

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[24] Ibid.

[25] Irving Maltzman, Eugene Eisman, and Lloyd O. Brooks, "Some Relationships Between Methods of Instruction, Personality Variables, and Problem Solving Behavior," The Journal of Educational Psychology, 47:71-78, February, 1956.

Scandura[26] found that information given indirectly acts as a catalyst. Instances of the desired concepts were presented and attention was directed so that the learner could abstract for himself. Evidence indicated that when prerequisite learning was inadequate, indirect information was of little value. Also, a presentation made too early was found to actually inhibit later discovery.

Haselrud and Meyers[27] have found that individually discovered principles were better retained and led to more transfer than was the case when subjects were told the principles in a direct manner.

On the other hand, the findings of Craig,[28] Kittel,[29] and Corman[30] dispute the results of the above studies. With

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26Joseph M. Scandura, "An Analysis of Exposition and Discovery Modes of Problem Solving Instruction," The Journal of Experimental Education, 33:155, Winter, 1964.

27G. M. Haselrud and S. Meyers, "The Transfer Value of Given and Individually Derived Principles," The Journal of Educational Psychology, 49:293-98, December, 1958.

28R. C. Craig, "Directed Versus Independent Discovery of Established Relations," The Journal of Educational Psychology, 47:223-34, April, 1956.

29Jack E. Kittell, "An Experimental Study of the Effect of External Direction During Learning on Transfer and Retention of Principles," The Journal of Educational Psychology, 48:391-405, November, 1957.

30Bernard R. Corman, "Learning: Problem Solving and Related Topics," Review of Educational Research, 28:459-64, December, 1958.

minor differences, in each of these investigations some outside direction proved more effective than no direction, despite earlier evidence that the efficacy of search behavior was increased with lesser amounts of information as guidance.

A series of studies were conducted at the University of Illinois which tested the relative influence of direct-detailed and directed discovery methods of teaching information and skill. One study in this series was conducted by Ray,[31] who utilized a population composed of 117 ninth grade junior high school boys who had been divided into three intelligence groups. The direct-detailed method involved continuous, positive presentation of all information, while the directed discovery method provided direct positive instructions for only that content considered to be basic. The remaining material was learned through carefully structured leading questions and hints to facilitate discovery.

The task upon which the subjects were tested involved instruction regarding the names and functions of the parts

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[31]Willis Eugene Ray, "An Experimental Comparison of Direct and Detailed and Directed Discovery Methods of Teaching Micrometer Principles and Skills" (unpublished Doctor's dissertation, University of Illinois, Urbana, 1957).

of the vernier micrometer, facts about the instrument, principles involved in reading the tool and manipulation and reading of the tool for actual measurement. An initial learning test was administered immediately following the treatment with retention and transfer being tested at one and again at six weeks. The analysis of variance technique was used to test the hypotheses.

Among the findings of the study were the following: (1) there was no significant difference in initial learning; (2) there was no significant difference in retention after one week; (3) there was a significantly greater retention after six weeks by the directed discovery treatment; and (4) there was no apparent interaction between teaching method and level of intelligence.

A similar experiment was conducted by Rowlett[32] to ascertain the relative effectiveness of the direct-detailed and the directed discovery methods of teaching selected principles of orthographic projection.

The directed discovery method involved the use of leading questions and hints while the direct-detailed

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[32] John D. Rowlett, "An Experimental Comparison of Direct-Detailed and Directed-Discovery Methods of Teaching Orthographic Projection Principles and Skills" (unpublished Doctor's dissertation, University of Illinois, Urbana, 1960).

procedure involved the imparting of highly specific instructions. A treatment by levels and by sex design was used in the experiment. Direct-detailed and directed discovery methods and a single control comprised the three treatments. High, average, and low ability groups constituted the three levels.

On the basis of his findings, Rowlett formulated the following conclusions:

1. No significant difference between direct-detailed and directed discovery methods in regard to initial learning.

2. The directed discovery method was superior to the direct-detailed method with regard to retention after twelve days.

3. The directed discovery method was superior to the direct-detailed method in terms of retention as measured six weeks after treatment.

4. No apparent interaction between teaching methods and ability levels.[33]

Moss[34] conducted an investigation involving the discovery method of teaching which provided continuous and

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[33] Ibid., p. 96.

[34] Jerome Moss, "The Relative Effectiveness of the Direct-Detailed and the Directed Discovery Methods of Teaching Letterpress Imposition," The Journal of Educational Research, 58:50-55, October, 1964.

comparative data to the findings of Ray,[35] Rowlett,[36] and a similar study by Grote.[37]

In comparing these studies and his own, Moss indicated that the many common elements possessed by the studies were apparently insufficient to overcome the differences among them. In addition to obvious population variations, the equivalency of the treatments, the organization of content, the level of difficulty of the learning task, and the nature and degree of the requirements of the criterion tests were all subject to question.

Moss identified two important findings on which these studies agreed: (1) the directed discovery methods proved to be at least as effective in instructing the low ability groups as the direct-detailed; and (2) some amount of increase in test scores was found for the control group between the initial test and the following retention test.

Petty,[38] in an article concerning the teaching of

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[35]Ray, loc. cit. [36]Rowlett, loc. cit.

[37]C. Nelson Grote, "A Comparison of the Relative Effectiveness of Direct-Detailed and Directed Discovery Methods of Teaching Selected Principles of Mechanics in the Area of Physics," The Journal of Educational Research, 58:50-55, October, 1964.

[38]Olan Petty, "Requiring Proof of Understanding," The Arithmetic Teacher, 2:121, November, 1955.

mathematics, maintains that the demonstration method of teaching arithmetic fails in many instances to help the child to see the reasons for various operations and to appreciate different arithmetical relationships while the discovery approach places much emphasis on meaning and understanding.

Petty listed several advantages of showing proof in arithmetic:

> 1. Students are not rushed through processes so hastily that no real understanding is fostered.
>
> 2. The use of concrete and semi-concrete procedures in deriving answers makes for better understanding.
>
> 3. The "proof method" is an excellent means of correcting initial errors.
>
> 4. The child's understanding of a problem or process may be readily checked by requiring proof of his answer by using a diagram or drawing.
>
> 5. The requirement of proof shows the advantage of shorter and more abstract methods of working problems.[39]

<u>Experiments in Descriptive Geometry</u>. A limited number of studies in descriptive geometry were located which related to various aspects of this investigation.

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[39] *Ibid.*, p. 123.

An early investigation conducted by Rugg was concerned extensively and exclusively with descriptive geometry and its effect upon spatial perception. Rugg's findings indicated that the training in mental manipulation of geometrical character received by students in descriptive geometry operated ". . . so as to substantially increase the students' ability in solving manipulative problems of a geometrical nature, but were entirely unrelated to the content of descriptive geometry."[40]

Sedgwick[41] reported on the results of a study which agree in part with the findings of Rugg.[42] The study, conducted at Southern Illinois University in 1961, was designed to ascertain whether or not a course in descriptive geometry would modify a student's spatial perception.

Two groups of subjects were selected and studied for one semester. The experimental group consisted of students enrolled in descriptive geometry classes who had not had a

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[40]Harold O. Rugg, Experimental Determination of Mental Discipline in School Studies: Descriptive Geometry and Mental Discipline (Baltimore: Warwick and York, 1916), pp. 97-98.

[41]Lorry K. Sedgwick, "Descriptive Geometry: Effect on Spatial Perception," The Industrial Arts Teacher, 22:15-17, November, 1962.

[42]Rugg, loc. cit.

previous course in descriptive geometry. The control group consisted of students who were not taking and had not taken a descriptive geometry course, and who were not taking any other drafting courses.

Thirty-six matched pairs of students evolved from the administration of the Space Relations Section of the Differential Aptitude Tests (DAT) Form A at the start of the semester. This provided two groups equal in means, variance, range and scores. At the end of the experimental period, the Form B of the same test was administered.

Sedgwick reported: (1) there was no valid support for the claim that instruction in descriptive geometry would improve the student's spatial perception; and (2) change and improvement in spatial perception could be affected more by maturation and general environmental experience rather than any specific experience.

Earle[43] conducted a study to ascertain which of four methods of presenting descriptive geometry problems required the least comprehension time. The methods employed were (1) the conventional method--the method most commonly used

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[43] James H. Earle, "An Experimental Comparison of Three Self-Instruction Formats for Descriptive Geometry" (unpublished Doctor's dissertation, Texas Agricultural and Mechanical University, College Station, 1964).

by textbooks; (2) a method whereby the problem was presented in sequential steps with the necessary text directly under each illustration; (3) the same format as used in the preceding method with the only difference being that each succeeding step was printed in red to more clearly distinguish it from the preceding steps; and (4) the lecture method.

The lecture method was found to be statistically superior to the conventional method, but inferior to the step method and the step method in color. It was concluded that the step method in color requires less student comprehension time than the step method and the lecture method; and that the step method requires less time than the conventional method. The step methods were recommended as possible formats for programed materials in descriptive geometry.

Chance[44] studied the relative effectiveness of a transparency-overhead projection approach and the chalkboard lecture-demonstration approach to teaching college level descriptive geometry. It was concluded that the transparency-overhead projection approach provided for maximum student learning in descriptive geometry.

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[44]Clayton W. Chance, "Teaching Engineering Graphics With Colored Transparencies--An Evaluation," The Journal of Engineering Graphics, 26:10-16, May, 1962.

A research project planned to evaluate the educational significance of an automated teaching device used to supplement instruction in descriptive geometry was directed by Brown[45] at The Ohio State University in 1963.

In this experiment, the control group received the traditional lecture-laboratory method of instruction while the experimental group experienced all new material with the aid of an automated teaching device. The automated teaching machine used in the study was a portable automatic sound slide film viewer complete with film strips and magnetic tapes. A convenience method of student selection was used in this experiment. Approximately one-hundred students assembled on the first day of the quarter at their assigned class time. From this group, students were divided into separate class sections and assigned to instructors. The size of each section was dependent upon the availability of staff and room capacity. This method of student selection provided a total population of forty-three students for the experiment.

On the basis of the findings of the study, the

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[45]William E. Brown, "A Research Project Designed to Evaluate the Use of an Automated Teaching Device in the Instruction of Engineering Graphics" (unpublished Doctor's dissertation, The Ohio State University, Columbus, 1964).

following conclusions were given:

> 1. The experimental method, which used the automated teaching machine, was superior to the traditional lecture-laboratory method for teaching descriptive geometry.
>
> 2. Individual progress and individual grades on laboratory problem exercises were improved in the experimental group over the group who had the traditional method.
>
> 3. The time factor was an important element for both student and instructor. The increase in available time in the experimental group provided the student with more laboratory time for completion of problem exercises and time to review the descriptive geometry principles by using the automated teaching machine. For the instructor, the available time provided more opportunities for individual student help and time to evaluate student problem exercises.[46]

An investigation by Amthor[47] compared the effectiveness of two selected methods of filmstrip instruction and the lecture-demonstration method in a descriptive geometry learning situation. The study consisted of two experiments conducted concurrently at Texas A and M University and at Stout State University during the fall semester of 1966. Both silent and sound filmstrips were used in the study.

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[46]Ibid., p. 54.

[47]William D. Amthor, "An Experimental Comparison of Three Methods for Presenting Selected Concepts of Descriptive Geometry" (unpublished Doctor's dissertation, Texas Agricultural and Mechanical University, College Station, 1967).

The following conclusions were stated:

1. The silent filmstrip and lecture-demonstration methods were equally effective in regard to initial learning of descriptive geometry principles.

2. The sound filmstrip and lecture-demonstration [methods] were equally effective in regard to the initial learning of descriptive geometry principles.

3. The silent filmstrip and sound filmstrip methods were equally effective in regard to the initial learning of descriptive geometry principles.

4. With reference to specific ability levels, the silent filmstrip, sound filmstrip, and lecture-demonstration methods were equally effective in regard to the initial learning of descriptive geometry.[48]

Experiments in Drafting. Numerous studies were reviewed which showed some relationship to the instructional approaches used in this experiment. Some of the studies are reported here.

Schanbacher[49] conducted an experimental investigation in 1961 to ascertain the relative effectiveness of teaching orthographic projection and pictorial

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[48]Ibid., p. 72.

[49]Eugene M. Schanbacher, "Identification and Analysis of Elements Versus the Conventional Approach in Teaching Drafting" (unpublished Doctor's dissertation, University of Missouri, Columbia, 1961).

representation by identifying surfaces, edges, and points in views with numbers and letters and analyzing their relationships. The investigation involved an experimental group of high school students who were taught drafting by the identification and analysis approach and a control group that was taught in the conventional manner.

The following conclusions were stated:

> 1. The teaching of drafting by the identification and analysis approach was more effective than the conventional method with respect to the number of correctly and accurately solved sketching problems.
>
> 2. The two approaches to the teaching of drafting were equally effective with respect to informational achievement, quality and quantity of drawing, ability of students to visualize, student attitude, and ability to solve sketching problems.[50]

Norman[51] conducted an experimental study to ascertain the relative effectiveness of employing freehand drawing techniques prior to using instruments in teaching the fundamentals of engineering drawing. It was concluded that the freehand method of instruction not only resulted

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[50] _Ibid_., p. 79.

[51] Ralph P. Norman, "An Experimental Investigation to Determine the Relative Effectiveness of Two Different Types of Teaching Methods in Engineering Drawing" (unpublished Doctor's dissertation, University of Minnesota, Minneapolis, 1955).

in superior learning during the freehand drawing period but that this superiority persisted throughout the experiment.

Film slides were found by Wilkes[52] to be more effective in terms of student behavioral changes in engineering drawing. The film slide method was compared with the lecture-demonstration a proach to teaching drawing.

In 1950, Richards[53] studied the effect on achievement in engineering drawing when emphasis was placed on the time element in instruction. Application of the experimental factor, as used in this study, appeared to have no appreciable effect upon drawing skill. Students drawing under pressure of time appeared to have a more favorable attitude toward the subject than those students not working under this pressure. In addition, it was found that instruction factors, such as ease of teaching, class discipline, and pleasant relations with students appeared to be more easily obtained by the instructor when his students were required to draw under pressure of time.

52Doran F. Wilkes, "A Comparison of Two Approaches to the Teaching of Engineering Drawing: Film Slides Versus the Conventional Approach" (unpublished Doctor's dissertation, University of Missouri, Columbia, 1966).

53Maurice F. Richards, "Effect of Emphasizing Time in the Teaching of Engineering Drawing" (unpublished Doctor's dissertation, University of Missouri, Columbia, 1950).

Beck[54] conducted an investigation which bears a relationship to the study under consideration inasmuch as similar experimental research designs were employed. The study was designed to ascertain whether or not sex differences were significant factors in the achievement level of college men and women enrolled in engineering drawing.

The design of the study was quasi-experimental in nature with the analysis of covariance technique used as a method of statistical control. The t-test and the analysis of covariance were the statistical techniques employed in the analysis of the data.

The criterion variables used in the study for purposes of comparison were: (1) technical information achievement, (2) manipulative skill development, (3) performance time, (4) visualization of spatial relationships, and (5) attitude toward engineering drawing.

On the basis of the results of the study, the following general conclusion was noted:

> Given time in which to overcome the manipulative skill deficiency, women would be able to achieve a level of performance in engineering drawing comparable to that of men.[55]

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[54]Burrel H. Beck, "A Comparison of the Achievement Level of College Men and Women Enrolled in Engineering Drawing" (unpublished Doctor's dissertation, University of Missouri, Columbia, 1967).

[55]*Ibid.*, p. 126.

CHAPTER II

FEATURES AND ORGANIZATION OF THE EXPERIMENT

In Chapter I the problem, purpose, scope and limitations of the study were discussed. Basic terms were defined, hypotheses were developed, and related literature was reviewed. This chapter describes the important features and the organizational framework of the research study.

The Research Design

This investigation was experimental in nature in that the researcher had some degree of control over the variables involved and the conditions under which the variables were observed.[1] Variables other than the experimental variable are typically controlled by: (1) physical manipulation, (2) selective manipulation (for example: a researcher may endeavor to hold conditions constant for the treatment groups), and (3) statistical manipulation.[2]

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[1] Carter V. Good and Douglas E. Scates, Methods of Research (New York: Appleton-Century-Crofts, Inc., 1954), p. 689.

[2] Deobold B. Van Dalen, Understanding Educational Research (New York: McGraw-Hill Book Company, 1966), p. 246.

Through the design of the study and selected pretests an attempt was made to control all variables except the effect which the experimental treatment (directed problem analysis) and the conventional treatment had upon selected criterion variables.

The treatment groups for this investigation consisted of students who were enrolled in two sections of ME 10 Descriptive Geometry scheduled during the fall semester, 1967-1968. Appropriate variations of the t-test were the statistical measures used to ascertain the relative effectiveness of the two approaches. The procedure followed was to vary the laboratory approach between the two groups enrolled in ME 10 Descriptive Geometry.

The design was quasi-experimental in that the researcher lacked ". . . the full control over the scheduling of experimental stimuli which makes a true experiment possible."[3] A design of this type permits the use of classes as they are normally scheduled. Pretests and certain features of the research design were employed by the researcher in an attempt to control for initial group differences. This design may be graphically depicted in

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[3]N. L. Gage (ed.), Handbook of Research on Teaching, American Education Research Association (Chicago: Rand McNally and Company, 1963), p. 204.

the following manner using the symbolism illustrated in the *Handbook of Research on Teaching*:[4]

$$\underline{O}\ \underline{X}_1\ \underline{O}\quad \underline{O}_3$$

$$\underline{O}\ \underline{X}_2\ \underline{O}\quad \underline{O}_4$$

The pretest and posttest observations for the groups experiencing laboratory Approaches A and B are represented by the symbol $\underline{O}$. The symbols $\underline{X}_1$ and $\underline{X}_2$ indicate the treatments experienced by the two groups; measures of retention for the groups experiencing laboratory Approaches A and B are represented by the symbols $\underline{O}_3$ and $\underline{O}_4$.

Control Factors. Control of variance is a fundamental technical function of a sound research design. Kerlinger[5] indicates that an efficient design should include an attempt to control the variance of extraneous variables that may have an effect on experimental outcomes. Complete control is seldom achieved, since identification and subsequent control of certain operating factors is extremely difficult. Insofar as possible, this investigation was designed to control those variables that could

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[4] *Ibid.*, pp. 171-246.

[5] Fred N. Kerlinger, *Foundations of Behavioral Research* (New York: Holt, Rinehart and Winston, Inc., 1965), p. 280.

conceivably affect the results. Elements which were held common for all students involved in the experiment were as follows:

1. Class instructor
2. Course content
3. Lecture periods
4. Length of laboratory periods
5. Text, reference material, and course outline
6. Equipment, drafting tools, and facilities
7. Lecture and laboratory quizzes
8. Instructional aids
9. Unit and mid-term examinations
10. Reading, laboratory and homework assignments
11. Lighting, heating, and ventilation of the laboratory
12. Time of day for lecture and laboratory sessions.

The students were not informed that an experiment was being conducted or that two different approaches to laboratory instruction were being used. The effects of other factors which were beyond the control of the investigator were assumed to operate equally within both groups or they were minimized through the design of the experiment and, when warranted, through appropriate statistical control.

Differential Treatments. The treatment variable of this investigation was the laboratory approach used in obtaining accurate solutions to graphical problems in descriptive geometry. Each course section was taught using a different laboratory approach.

In one section the "directed problem analysis approach" (Approach A) was used for all assignments. This form of laboratory procedure required each student to identify, separate, and order, in written form, the constituent elements in the problem or steps under consideration prior to attempting an accurate solution. The student was encouraged to develop complete or partial illustrative sketches of tentative solutions to supplement the analysis procedure. In this approach, the student progressed from group lecture to the development of an analysis of each problem which led to the final accurate solution of assigned problems. The experimenter developed a problem analysis form[6] which was used with this approach.

A second section was taught using the "conventional approach" (Approach B). This form of laboratory procedure allowed the student to attempt an accurate solution to the problem under consideration without first developing a structured, written analysis or supplemental sketch of the problem. In this approach, no mention was made of the directed problem analysis technique as the student progressed from group lecture directly to attempted final accurate solutions of assigned problems.

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[6] See Appendix D.

Both sections were taught by the same instructor, presenting identical instructional material to both groups. The laboratory problems, homework assignments, tests, and informational content were the same for both groups.

Nature of and Selection of the Population

The population studied consisted of university students enrolled in ME 10 Descriptive Geometry in the College of Engineering at the University of Missouri - Columbia during the fall semester of the 1967-1968 school year. This course was required of or regularly taken by students majoring in one of the several engineering departments of the College of Engineering.

During the course of the investigation, laboratory supervision and related instruction was carried out by a regular full-time instructor of engineering drawing in the Department of Mechanical Engineering, University of Missouri - Columbia. The investigator acted in a coordinating capacity for the duration of the experimental period but was not actively involved with the subjects of the investigation.

A total of 54 students were enrolled in the two sections of ME 10 Descriptive Geometry scheduled for the fall semester, 1967-1968. The study was designed to accept both sections as assigned and to utilize the analysis of covariance technique in the event that initial differences existed between the two groups. Since significant initial differences were not present, the t-test was used for the statistical analysis of the data.

Pretests were administered and personal data collected from 52 students during the first week of the course. All 52 students completed the eight week experimental period. Of this number, 50 students completed both tests of retention which were administered three weeks after the treatment.

Schedule of Classes

The two sections of ME 10 Descriptive Geometry which were available for this experiment had been previously scheduled by the Department of Mechanical Engineering and the students had been assigned to the classes on the basis of space availability. The schedule of laboratory and lecture time included in the experiment is shown in Table I.

The experimental treatment was randomly assigned to one of the two sections on the basis of a coin toss. The "directed problem analysis approach" (Approach A) was used with section B. The "conventional approach" (Approach B) was used with section A.

TABLE I

LABORATORY AND LECTURE TIME SCHEDULE

Approach	Section	Laboratory	Lecture	Day
Conventional	A	9:40-11:30		M-F
			12:40-1:30	T
Directed Problem Analysis	B	9:40-11:30		T-Th
			12:40-1:30	T

The Nature of ME 10 Descriptive Geometry

The course content was not considered to be an experimental factor in the study. ME 10 Descriptive Geometry had been designed several years prior to this investigation by Professor Alfred S. Gaskell, Supervisor of Engineering Graphics. The course was fully accepted by engineering educators in the College of Engineering at the University of Missouri - Columbia and approved as a part of the engineering curriculum.

The first half of the course was devoted to the study of selected elements of descriptive geometry while the remainder involved a study of kinematics and motion analysis. Since this investigation was concerned with instruction in descriptive geometry, the first eight weeks of the semester constituted the experimental period for the investigation.

The major topics or large units included in the descriptive geometry section of the course were similar to those identified by Earle[7] in his research investigation as being representative of a basic course in descriptive geometry.

The major topics included in the descriptive geometry section of the course were: true length, bearing and slope of lines; lines and planes; perpendicularity; parallelism; shortest level, perpendicular and specified slope lines; piercing point; dihedral angle and angle between line and plane; coplanar and noncoplanar vectors; and intersection of plane surface solids.

Selection of Assignments

Laboratory and homework assignments correlated with the illustrated lecture presentations in the course were regularly made. The fifth edition of Warner's Applied Descriptive Geometry[8] was the text used by all students.

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[7]James H. Earle, "An Experimental Comparison of Three Self-Instruction Formats for Descriptive Geometry" (unpublished Doctor's dissertation, Texas Agricultural and Mechanical University, College Station, 1964).

[8]Frank M. Warner and Mathew McNeary, Applied Descriptive Geometry (fifth edition; New York: McGraw-Hill Book Company, Inc., 1959).

This was the regular textbook for the course and all students were expected to obtain a copy. Homework assignments and graphic problems to be completed in the laboratory were taken from the text and from Gaskell's Engineering Descriptive Geometry Laboratory Work Sheets[9] and Homework Sheets.[10]

A detailed laboratory schedule was followed by the instructor in teaching both sections. This schedule outlined, by period, all laboratory assignments, quizzes, and major examinations. Specific laboratory assignments were made to both groups at the beginning of each period. At the close of the period, certain of these assignments were collected for purposes of critique, correction and grading. These assignments were returned to the students at the next regularly scheduled laboratory session. Homework and reading assignments were made at the close of laboratory periods. These assignments were to be completed prior to the next laboratory period.

A composite outline by period and a schedule of homework assignments were given to all students prior to

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[9]Alfred S. Gaskell, Engineering Descriptive Geometry Laboratory Work Sheets (Columbia: Lucas Brothers Publishers, 1966).

[10]Alfred S. Gaskell, Engineering Descriptive Geometry Homework Sheets (Columbia: Lucas Brothers Publishers, 1966).

receiving any instruction in the course. Copies of these schedules and the laboratory schedule are included in Appendix C.

Physical Facilities

The same drafting laboratory was assigned for use by both sections in this study. Lighting, heating and ventilation were maintained at as near ideal conditions as possible. Equipment and furnishings, such as drafting tables and stools, were in excellent condition and of the same design. Single drawers within the drafting tables were assigned to students for storage of supplies and equipment. Students were expected to purchase the necessary individual drafting equipment and supplies. These were made available through either the University Book Store or the Missouri Book Store.

All students in ME 10 Descriptive Geometry attended a common lecture session of one hour in length each week in the auditorium of the Electrical Engineering Building. Each student was assigned to an auditorium tablet-arm chair. Film slides,[11] prepared by the Supervisor of

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[11] See Appendix C for description of Gaskell Film Slides.

Engineering Graphics, were used to illustrate each lecture. The slides were projected to an 8' x 8' beaded screen with the aid of an automatic Kodak Carousel projector. The images were plainly visible from all parts of the auditorium. The slides were changed with the aid of a remote control device thus allowing the lecturer to face his audience while discussing the slides. The auditorium was dimly lighted during the slide presentation to permit note-taking by students.

Criteria for Comparison

The basis for comparing the relative effectiveness of the two approaches to the teaching of selected elements of descriptive geometry were as follows: (1) ability to solve graphic problems, (2) visualization of spatial relationships, (3) ability to analyze and reason abstractly, (4) informational achievement, and (5) attitude toward descriptive geometry.

Summary

This investigation was conducted as a two-group controlled experiment. The study employed the use of a quasi-experimental research design in comparing the relative effectiveness of two approaches to the teaching of selected elements of descriptive geometry.

All factors with the exception of the laboratory approach to teaching descriptive geometry were held constant or controlled insofar as was possible.

The two instructional approaches to descriptive geometry used in the study were the "directed problem analysis approach" (Approach A) and the "conventional approach" (Approach B).

The population participating in the study included 52 students enrolled in two sections of ME 10 Descriptive Geometry in the College of Engineering at the University of Missouri - Columbia during the fall semester of the 1967-1968 school year. A total of 28 students were included in the section which utilized laboratory Approach A while the section in which Approach B was employed included 24 students.

The instructional content of ME 10 Descriptive Geometry was considered to be representative of a basic course in this subject.

The textbook, homework and laboratory work sheets, laboratory schedule, composite outline by period, and homework assignment sheets were the same for both sections. Both sections were taught by the same instructor.

All students included in the study received their instruction in the same laboratory, had access to similar equipment, and attended the same one-hour weekly lectures. Insofar as the researcher could ascertain, the physical facilities utilized in the experiment were equal for both sections.

The relative effectiveness of the two approaches to teaching selected elements of descriptive geometry was assessed through a comparison of the following student behavior variables: (1) performance in the solution of graphical problems, (2) spatial perception, (3) abstract reasoning ability, (4) technical information achievement, and (5) student attitude toward descriptive geometry.

CHAPTER III

PREPARING FOR AND CONDUCTING THE EXPERIMENT

The various features and organization of the experiment were described in Chapter II. This chapter provides a detailed account of the process of preparing for and conducting the experiment. Central to this process was the selection and development of tests which were used to: (1) assess the initial status of students, (2) secure measures of change as a result of treatment, and (3) ascertain the extent to which these changes were observable after a period of three weeks.

Initial Status of Students

Since the experimenter had no control over the assignment of students to classes and since the number of students available for the experiment was limited, no attempt was made to match students who were participants in this investigation. The experimenter decided to accept the groups as assigned and to attempt control of any initial differences between the two groups through certain features of the research design, appropriate statistical procedures, and selected pretests. These methods allowed for a degree of control over the variables that were assumed most likely to affect the end results of the experiment, namely: (1) scholastic aptitude, and (2) knowledge of drawing related to descriptive geometry. In an attempt to ascertain the initial status of the two groups on other selected factors, data relative to age and semesters of college work completed by each student were obtained. In addition, pretests were administered to obtain initial measures for the criterion variables of spatial perception, abstract reasoning, and student attitude toward the course.

Selection of Tests

For a study of this nature to be of value, a high degree of confidence must be accorded the instruments used in measuring the variables which serve as a basis for comparisons. For this reason, the investigator preferred to use recognized standardized tests rather than teacher-made tests wherever possible; hence, an exhaustive search was undertaken for appropriate published tests.

Scholastic Aptitude. Perhaps the most important factor related to academic success is the ability to understand and manipulate abstract symbols in the form of word meanings or verbal relationships. For this reason, most tests that have been developed for the purpose of predicting academic success or ability to learn have endeavored primarily to measure the individual's abilities in this respect.[1] One such test, the Cooperative School and College Ability Test (SCAT),[2] was selected to obtain a measure of scholastic aptitude. The SCAT, Form 1A, is used in a battery of tests administered to entering students by the Testing and Counseling Service of the University of Missouri; hence, scores for most students participating in the experiment were readily available.

It is generally conceded that the composite score on an examination of this type yields as predictive an index of college success as has been provided through various scholarship and admissions testing programs.

The SCAT series of six tests can best and most accurately be described as academic aptitude tests. It is generally agreed that they were specifically designed to ". . . aid in estimating the capacity of a student to undertake the academic work of the next higher level of

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[1] William J. Micheels and M. Ray Karnes, Measuring Educational Achievement (New York: McGraw-Hill Book Company, Inc., 1950), p. 29.

[2] Oscar K. Buros (ed.), The Sixth Mental Measurements Yearbook (Highland Park: The Gryphon Press, 1965), p. 715.

schooling."[3]

In his review of the test for the Sixth Mental Measurements Yearbook, Green regards the SCAT series as a ". . . set of very good scholastic aptitude tests which probably is in most ways the equal of any of its competitors."[4]

In a discussion regarding the predictive value of the test, Green notes that:

> . . . If, however, one is primarily concerned with prediction of general overall levels of future performance, SCAT can clearly be recommended from grades 5 through 16. Or if one wishes to install a system which will focus on academic aptitude while at the same time avoiding the use of IQ labels with all the potential for mischief that such labels carry, then SCAT appears to be ready made for him.[5]

An internal consistency reliability of at least .95, using the Kuder-Richardson formula 20, is reported for the total score in all grades. The reliability coefficients of verbal scores are at least .92; and the reliability

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[3]Technical Report, Cooperative School and College Ability Tests (Princeton, New Jersey: Cooperative Test Division, Educational Testing Service, 1957), p. 5.

[4]Russel F. Green, "Cooperative School and College Ability Tests," Sixth Mental Measurements Yearbook, Oscar K. Buros, ed. (Highland Park: The Gryphon Press, 1965), p. 718.

[5]Ibid.

coefficients for the quantitative scores range from a high of .93 in grade 13, to a low of .88 in grade 5. The following reliability coefficients are reported for Form 1A: verbal .92, quantitative .93, and total .95. The ratio of the verbal to the quantitative standard deviation varies from almost 1:1 in grade 13 to approximately 1.4:1 in grade 9. As grade level increases, the correlation between verbal and quantitative steadily decreases which is in agreement with the literature on the development of abilities.[6]

Knowledge of Drawing Related to Descriptive Geometry. Tests specifically designed to measure background and achievement of technical information in descriptive geometry were not available. However, a general drafting test developed by Blum[7] covers several units of instruction which have a direct relationship to certain units taught in descriptive geometry. Because of this factor and because it afforded some indication of general knowledge of

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[6]Technical Report, op. cit., pp. 11-12.

[7]Robert E. Blum, "Is a Nationwide Drafting Test Possible?" Industrial Arts and Vocational Education, 54:31-33, May, 1965.

drafting, Blum's Comprehensive General Drafting Examination[8] was chosen as one of the measures to assess initial group status.

The test is comprehensive in nature and covers a variety of items on all units of drafting instruction. The test was designed for use in advanced placement as well as in the analysis of instruction and curriculum.

The Kuder-Richardson method of inter-item consistency was used in computing test reliabilities. For all students completing four or five quarter hour or three semester hour college drafting courses the reliability coefficient was reported to be .92 with a standard error of measurement of 5.24. In addition, the composite score, which is considered the best overall measure yielded by the examination, was found to be 83.73 with a standard deviation of 18.54.[9]

Information Form. Information regarding the students' age and the number of semesters of college work completed was secured from the student information section of the answer sheet developed by the experimenter and used in conjunction with the attitude pretest. This information

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[8]See Appendix A for a copy of this test.

[9]Robert Eugene Blum, "Comprehensive General Drafting Examination: Normative Information," 1965 (Mimeographed.).

was verified by checking it against a student information form completed by each student during the initial class period which had been placed on file with the supervisor of engineering graphics. A random check of the records for thirty per cent of the students involved in the study provided additional verification of the accuracy of student responses concerning age and semesters of college work completed. These records were located in the Dean's Office, College of Engineering at the University of Missouri - Columbia.

Spatial Perception. The space relations section of the Differential Aptitude Tests (DAT)[10] is widely recognized as a test designed to measure one's ability to think in spatial terms. More specifically, the test endeavors to evaluate the ability to manipulate "things" mentally and to create a structure in one's mind from a plan. This ability is considered an essential part of such fields as drafting, architecture, art, and decoration. In addition, tests of spatial perception have a general utility in the prediction of success in such areas as engineering and mechanical design. In essence, it is a desirable attribute whenever

[10] See Appendix A

there is a need for the visualization of objects in three dimensions.[11]

The mean reliability coefficients of the space relations section of the DAT, Form L are reported as .94 for males and .93 for females; the average means reported for males and females are 31.1 and 27.0, respectively. The average standard deviations are 12.1 for males and 11.1 for females.[12] The space relations section of the DAT, Form L was the test selected to measure the variable of spatial perception.

Abstract Reasoning. The ability to logically analyze and perceive the relationships regarding the abstractness of lines, points and planes as they occupy space is considered a desirable outcome for students in descriptive geometry. Wellman[13] has suggested that the development of this ability is a basic objective of descriptive geometry. The abstract reasoning section of the Differential Aptitude

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[11]George K. Bennett, Harold G. Seashore, and Alexander G. Wesman, Manual for the Differential Aptitude Tests (fourth edition; New York: The Psychological Corporation, 1966), p. 9.

[12]Ibid., Section 6, p. 4.

[13]B. Leighton Wellman, Technical Descriptive Geometry (second edition; New York: McGraw-Hill Book Company, Inc., 1957), p. v.

Tests (DAT) is intended as a nonverbal measure of the student's reasoning ability. This test is designed to measure an individual's ability to perceive relationships in abstract figure patterns. Such an ability is considered relevant when the subject, curriculum, profession, or vocation requires perception of relationships among things rather than among words or numbers. In this sense, it may be properly grouped with tests of spatial perception.[14]

The mean reliability coefficients of the abstract reasoning section of the DAT, Form L are reported as .91 for males and .93 for females; the average means reported for males and females are 32.0 and 30.8, respectively. The average standard deviations are 9.6 for males and 10.5 for females.[15] The abstract reasoning section of the DAT, Form L was the test selected to measure the variable of abstract reasoning.

Attitude Scale. A measure of the students' initial attitude toward the course was obtained by using Remmers' Scale for Measuring Attitude Toward Any School Subject, Form A. The scale consists of a series of seventeen

[14] Bennett, op. cit., Section 1, p. 7.

[15] Ibid., Section 6, p. 4.

statements arranged on a continuum. The statements range from those which are highly favorable, through those which indicate an indifference attitude, to those suggesting negative attitudes. Students responded to those statements with which they agreed. Scores may range from a low of 1.0, a negative attitude, through 6.0, an indication of indifference, to a high of 10.3, considered a highly favorable attitude.[16]

The reliability of the scale is reported as ranging from .71 to .92. Although the validity of the scale as a pretest has not been established, the accompanying manual states that:

> . . . these scales have demonstrated validity both against Thurstone's specific scales with which they show typically almost perfect correlations and in differentiating among attitudes known to differ among various groups.[17]

Administering and Scoring of Pretests

As previously stated, the scholastic aptitude test scores were obtained from the records of the Testing and Counseling Service at the University of Missouri - Columbia.

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[16] H. H. Remmers, Manual for the Purdue Master Attitude Scales (West Lafayette, Indiana: University Book Store, 1960), p. 6.

[17] Ibid., p. 2.

It is assumed that these tests were uniformly administered and scored according to recommended procedures.

The pretest of knowledge of drawing related to descriptive geometry was administered by the investigator on the evening following the first lecture period of the fall semester. The test was administered in the Electrical Engineering Auditorium which was equipped with regular tablet-arm seats. The day preceding and the day following the group test administration were set aside by the investigator to accommodate the testing of students with schedule conflicts. Students were told that the results of this test would be used to ascertain their prior achievement in general drafting and drafting related to descriptive geometry. Students were informed that the results would not affect their course grade, but they were to do as well as possible.

The instructions for the test were read aloud by the investigator after which students were given an opportunity to ask questions concerning the instructions. Students were then told to complete the test, answering all items. No time limit was imposed and students were allowed to leave the room upon completion of the test.

The spatial relations, abstract reasoning, and the attitude scale pretests were administered by the experimenter to each section separately during the first regularly scheduled laboratory period of the fall semester. The same laboratory provided the setting for the administration of these tests to both sections. Students were informed that the results of these tests would not affect their course grade but would be used as an aid in analyzing and planning future instructional presentations of the course and as an indication of student attitude changes toward the course. A twenty-five minute time limit was enforced for both the spatial relations and abstract reasoning tests. Instructions were read by the investigator and followed by the students.

Instructions for completing the student information section of the answer sheet used for the attitude scale were read by the investigator. After the student information section of the answer sheet was completed, instructions for placing responses to the attitude scale were read by the investigator and students were directed to respond to the scale. The attitude scale was hand scored by the investigator and verified by an instructor in engineering drawing.

Standard answer sheets were used to facilitate machine scoring of the pretests for knowledge of drawing related to descriptive geometry as well as the spatial relations and abstract reasoning pretests. Having made prior arrangements, all of the above mentioned tests were machine scored through the facilities of the Missouri State-Wide Testing Service and the tests were analyzed by the Computer Research Center on the Columbia Campus of the University of Missouri.

Instruments Used to Measure Criterion Variables

Two of the experimental variables which were used as criterion measures required the use of teacher-constructed examinations. The criterion measures involved were graphic problem solving ability and informational achievement in descriptive geometry.

Graphic Problem Performance Test. A graphic problem performance test was judged to be the most valid method of assessing graphic problem solving ability since only a genuine understanding of concepts would enable a student to respond correctly. No applicable standardized performance tests for measuring graphic problem solving ability were available; hence, alternate forms of a graphic problem performance test were developed by the experimenter. The proposed tests were submitted to the supervisor of engineering graphics and the instructor of ME 10 Descriptive

Geometry for validation. The course outline was referred to as an aid in each person's evaluation of the test's validity. After subsequent modification and revision of the proposed test, it was agreed that the test would provide a valid measure of the students' graphic problem solving ability covering the major topics included in the study.

In an attempt to test the retention of students, in terms of graphic problem solving ability, alternate forms of a graphic problem performance test were designed by the experimenter. These tests were similar, but not identical to the tests used to secure a measure of graphic problem solving ability after treatment. The same validation procedures which were used for the test of performance were applied to the retention test of performance. Copies of both of these examinations together with the criteria for evaluation appear in Appendix B.

Informational Achievement Test. There were no available standardized tests which would adequately measure technical information achievement in descriptive geometry; therefore, an objective-type test for this purpose was developed by the investigator. Items for the test were selected on the basis of the established criteria for a good test as described by Micheels and Karnes.[18] Test items were formulated from a comprehensive analysis of course content included in the experiment.

The items were organized into test form and submitted to the supervisor of engineering graphics and the instructor of ME 10 Descriptive Geometry for validation. The course outline was used as an aid by these individuals in their evaluation of the test's validity. In its final modified and revised form, it was agreed that the test would provide a valid measure of informational achievement covering the major topics included in the study. Although predetermined coefficients of reliability were not available, reliability characteristics of the test were secured through application of the Kuder-Richardson formula 20 to the posttest scores of informational achievement of subjects included in the experiment. A reliability index of .72 was obtained by the group experiencing Approach A while the group taught by Approach B attained a reliability index of .82. The reliability characteristics of both groups combined exhibited an index of .96.

To obtain a measure of the retention of students experiencing the differential treatments, in terms of

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[18]Micheels, op. cit., pp. 103-04.

informational achievement, the same test of informational achievement was administered to both groups three weeks after treatment. A copy of this examination appears in Appendix B.

Administering and Scoring the Tests

The tests of graphic problem performance and informational achievement were administered at the end of the experimental period by the regularly assigned laboratory instructor. The tests were of the type normally used for mid-term examinations.

Alternate forms of the graphic problem performance test were used to prevent students from comparing work. Problems in the alternate forms were of a similar type, but not identical. Instructions were read aloud by the test administrator as students read silently. Immediately following, questions were answered regarding the instructions. Students were given a total of 120 minutes to complete the examination.

A panel of three instructors experienced in teaching descriptive geometry, including the investigator, evaluated the performance examination. The performance grade for each student was an average of grades assigned by each of the three panel members. In an effort to provide uniformity in scoring, evaluative criteria were devised for each problem which aided the panel members in their evaluation of the student solutions.

The informational achievement test was administered during the first half of the regularly scheduled laboratory period following the performance examination. The laboratory instructor served as the test administrator and read the instructions orally to the students. After answering questions regarding the instructions, the students were allowed approximately 50 minutes for completion of the examination. The tests were scored by the investigator and verified by an instructor of drafting at the University of Missouri - Columbia.

The retention tests of graphic performance and informational achievement were administered three weeks after treatment by the regular laboratory instructor.

The same panel members who scored the posttest of performance also scored the retention test of performance. The performance grade for each student was an average of grades assigned by each of the three panel members. To provide uniformity in scoring, evaluative criteria, similar to that used for the posttest of performance, were devised for each problem.

The retention test of informational achievement was scored by the investigator and verified by an instructor of drafting at the University.

Coordination of Instruction

In this investigation, a majority of the instructional content was presented by the supervisor of engineering graphics to members of both groups at the same time during lectures. The supervisor was experienced in the presentation of instructional content in this manner having conducted such lectures at the college and university level for a number of years. Much of the instructional content was presented visually with the aid of especially designed film slides prepared by the supervisor.

In addition, a certain amount of specific instruction was afforded both groups by the regular laboratory instructor during the separate laboratory sessions. Since it would be highly improbable that an instructor could present a single lesson, to two classes at different times in an identical manner with the same results, the investigator makes no claim that instruction in both laboratory sections of descriptive geometry was identical. However, a determined effort was made to organize and present the instructional content in such a manner so that differences in instructional effectiveness were minimal. The laboratory instructor was experienced in supervising laboratory instruction to several drafting classes per day. He had taught multiple sections of college level engineering drawing and descriptive geometry for several years at the University of Missouri - Columbia prior to this investigation.

A composite outline by period and a homework assignment schedule were given to each student at the beginning of the semester. The composite outline provided a calendar of instructional topics and examinations as presented in lecture and laboratory sessions or homework assignments. The homework assignment schedule provided reading assignments and graphic problem assignments, as well as study questions to aid the student in his preparation. Any additional instructional sheets were uniformly presented to both groups during the experiment.

The laboratory instructor followed a detailed laboratory schedule which outlined, by period, all laboratory assignments, quizzes and major examinations. The investigator coordinated laboratory instruction to insure that content was presented to both groups in the same sequence, on the same day, using identical media. Close coordination was maintained with the laboratory instructor in an effort to avoid special assistance for any students since this might influence the results of the study. The laboratory instructor was knowledgeable of both treatments used in this experiment.

Laboratory Instruction Procedures

The procedures followed with the differential approaches to laboratory instruction in descriptive geometry are described herein. General rules and procedures are also described.

Directed Problem Analysis. The laboratory section was scheduled for two 55-minute periods, running concurrently, and met twice each week during the semester. Students worked assigned problems during these periods, except on certain days when examinations were scheduled. A portion of the second laboratory period was used to present instruction in the techniques of the "directed problem analysis" approach for the group who would employ this technique during the balance of the experiment. In this approach, the student attempted to identify, separate, and order, in written form, the constituent elements or factors inherent in the assigned problem prior to attempting an accurate solution. The student was encouraged to use complete or partial illustrative sketches of tentative solutions to supplement this procedure. The following procedures were incorporated for use with this approach:

1. Using the forms supplied by the instructor, the student developed a written analysis for each assigned problem prior to attempting an accurate solution.

2. The student was required to submit his completed analysis of the problem and the accompanying laboratory problem work sheet for a preliminary critique by the instructor. The instructor initialed both the analysis form and the problem work sheet prior to returning these to the student.

3. The student then attempted an accurate graphic solution to the problem (drawing on the laboratory problem work sheet) with the aid of his completed analysis.

4. As required, the student submitted both the analysis form and the completed problem work sheet to the instructor for correction and grading at the close of the laboratory period.

Specific assignments were made at the beginning of each laboratory period according to the schedule of laboratory assignments. At the close of each period, certain representative assignments were collected for purposes of correction and grading. The evaluation of these assignments was accomplished by the instructor outside of the regular laboratory period. Comments regarding the correctness and completeness of the problem analysis and the graphic problem solution were written on the analysis form and problem work sheet, respectively, along with numerical grades. Evaluated assignments with the analysis were returned to the students at the next regularly scheduled laboratory period. After being allowed to examine the corrected problem solution and analysis, the problem analysis was again collected and retained by the instructor. A typical laboratory assignment with completed problem analysis and graphic problem solution appears in Appendix D.

Conventional Approach. The laboratory section was scheduled for two 55-minute periods, running concurrently, meeting twice each week during the semester. Students worked assigned problems during these periods, except on certain days when examinations were scheduled. In this approach, students attempted accurate solutions to the problems under consideration without the aid of any preliminary, structured, written or graphical analysis. The instructor was available to answer questions or give assistance.

Specific assignments were made at the beginning of each laboratory period according to the schedule of laboratory assignments. At the close of each period, certain representative assignments were collected for purposes of correction and grading. The evaluation of these assignments was accomplished by the instructor outside of the regular laboratory period. Comments regarding the correctness and completeness of the graphic problem solutions were written on the problem work sheet along with numerical grades. Evaluated assignments were returned to the students at the next regularly scheduled laboratory period.

General Rules and Procedures. Following are the general rules and procedures which pertained to both groups:

1. The student was held responsible for all lecture information and discussion. Also, he was held responsible for all assigned text material whether formally discussed or not.

2. Both groups were assigned the same graphic problems from the schedule of laboratory assignments.

3. All assigned graphic problems were graded on a basis of 10 to 0. A score of 10 was considered excellent and 0, failing. Certain assignments were collected at the close of the class period each day.

4. Laboratory work, quizzes, or examinations which were missed for an unexcused reason were expected to be made up within a time period prescribed by the instructor.

5. All students were expected to remain in the laboratory for the required length of time.

Course Examinations and Quizzes

Testing was not an experimental factor in the study, but it was considered an essential evaluative activity. During the course of the investigation one unit examination and several quizzes were administered to both groups as a part of the regular instructional program. Quizzes were normally given unannounced and usually covered instructional content presented in lecture, laboratory, or in assigned readings. They were administered periodically in both the laboratory and the common lecture with allowed completion times ranging from 10 to 20 minutes.

Alternate forms were used for the unit examination to prevent students seated at adjoining tables from comparing work. This examination was composed of objective and performance items. Students were allowed the full laboratory period for the completion of the unit examination. All quizzes and examinations were graded by the laboratory instructor. Solutions and answers were discussed in both sections during the next regularly scheduled laboratory period following the administration of the quiz or examination.

Records Maintained

In addition to records of grades on required laboratory assignments as well as all quizzes and examinations, a record of the attendance of each student was maintained. It was deemed important to hold absences to a minimum in order to provide equal amounts of instructional time for all students. Students with legitimate reasons for being absent were allowed to receive makeup instruction from the instructor upon request.

An analysis of the attendance record of both groups reveals that each student was absent an average of about one class period. The record of attendance for each student is shown in Appendix E.

Summary

Before any differences in results could be attributed to the differential treatments, it was essential to test for the initial status of both groups. The primary factors which were chosen for the purpose of ascertaining the initial status of the subjects were: (1) scholastic aptitude, and (2) knowledge of drawing related to descriptive geometry. Additional data relative to the factors of age and semesters of college work completed were secured.

Also, initial measures were obtained for the criterion variables of spatial perception, abstract reasoning, and attitude toward descriptive geometry.

The Cooperative School and College Ability Test (SCAT), Form 1A was selected to measure scholastic ability. Knowledge of drawing related to descriptive geometry was ascertained by administering Blum's Comprehensive General Drafting Examination, and Remmers' Scale for Measuring Attitude Toward Any School Subject was used to assess student attitude toward descriptive geometry. Appropriate sections of the Differential Aptitude Tests (DAT), Form L, were used to measure spatial perception and abstract reasoning ability.

Each student's age and the number of semesters of college work completed were secured from an information form administered at the time initial attitude was assessed. The accuracy of this information was verified by a random check of the student records in the office of the Dean of Engineering and a check of student information forms on file with the supervisor of engineering graphics.

The Testing and Counseling Service of the University of Missouri - Columbia was responsible for the administration and scoring of the Cooperative School and College Ability Test. The pretests for knowledge of drawing related to descriptive geometry, spatial perception, and abstract reasoning were administered by the investigator and machine-scored through the facilities of the Missouri State-Wide Testing Service. The tests were analyzed by the Computer Research Center on the Columbia Campus of the University of Missouri.

The criterion variables of graphic problem solving ability and informational achievement required the use of teacher-constructed examinations since no relevant standardized tests were available. Both examinations were validated by a panel of three experienced teachers of descriptive geometry.

The informational achievement test was objective in nature and exhibited a reliability index of .96 for both groups combined. The tests of graphic problem performance and informational achievement were administered at the conclusion of the experiment by the laboratory instructor.

The same informational achievement test was administered to both groups three weeks after treatment in order to obtain a measure of retention for this variable. In addition, a test similar, but not identical to the posttest of performance was devised to secure a measure of retention three weeks after treatment. The same validation procedure that was used with the posttest of performance was applied to the retention test. A trio of experienced drafting instructors at the University of Missouri - Columbia evaluated both the posttests and retention tests of performance. The posttests and retention tests of informational achievement were scored by the investigator and verified by an instructor of drafting at the University. All other quizzes and examinations were administered under the supervision of the investigator or the laboratory instructor of descriptive geometry.

In an attempt to minimize instructional differences between the two groups, a composite outline and a homework assignment schedule were provided to each student. The laboratory instructor followed a detailed laboratory schedule which outlined, by period, all laboratory assignments, quizzes, and examinations. An experienced professor of engineering graphics conducted the weekly lecture sessions attended by all students enrolled in ME 10 Descriptive Geometry. Much of the instructional content was presented visually with the aid of film slides specifically designed for the course.

An experienced instructor of descriptive geometry supervised the laboratory experiences of both groups. The investigator acted in a coordinating capacity during the experiment, working closely with both the supervisor of engineering graphics and the laboratory instructor to assure proper implementation of the differential treatments.

Students who experienced the "directed problem analysis" approach attempted to identify and order, in writing, the constituent elements or factors inherent in the assigned problems prior to attempting accurate solutions. The students were encouraged to use illustrative sketches of tentative solutions to supplement the written analysis procedure.

In contrast, students experiencing the "conventional approach" attempted accurate solutions to the problems under consideration without the aid of a preliminary, structured, written or graphical analysis. The instructor was available to answer questions or lend assistance.

Students in both groups were held responsible for all lecture information, discussion, and assigned readings. Identical laboratory problems were assigned to both groups and these were graded using a uniform marking system.

One unit examination and several quizzes were administered during the experimental period as a part of the regular instructional program.

Grades on required laboratory assignments, quizzes, and examinations were recorded. In addition, a record of attendance indicated that each student in the two sections was absent an average of approximately one class period.

CHAPTER IV

MEASUREMENT AND ANALYSIS OF RESULTS

Procedures involved in ascertaining the initial status of students and of preparing for and conducting the experiment were provided in Chapter III. This chapter provides a description of the process of measuring and analyzing the data as well as a report of the experimental findings. The initial status of students is also reported.

Initial Status of Students

Data from the total research population were analyzed to ascertain whether or not initial differences were present between the two groups experiencing instruction in descriptive geometry by two different approaches.

Analysis of Initial Status of Students

The statistical procedure for t-tests of uncorrelated means as described by Guilford,[1] was used to analyze the differences between the two approaches for each of four

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[1] J. P. Guilford, Fundamental Statistics in Psychology and Education (New York: McGraw-Hill Book Company, 1965), p. 183.

control variables. Statistical significance for obtained t-values was tested at the five per cent level of confidence, employing the appropriate degrees of freedom for each set of data. The t-value with summary data for each control variable is shown in Table II.

The "directed problem analysis" group had a slight advantage with respect to mean scholastic aptitude and had achieved a higher mean score on the test of knowledge of drawing related to descriptive geometry, while the "conventional approach" group was slightly older and had been enrolled in college for a slightly longer period of time. However, none of the above advantages proved to be greater than chance. Hence, the differences of initial status between the groups experiencing the differential treatments were not statistically significant with respect to scholastic aptitude, knowledge of drawing related to descriptive geometry, age, or semesters of college work completed. Composite scores of the initial status of all students included in the experiment are shown in Appendix E.

Results of Student Performance on Criterion Variables

Selected student behavioral changes, which may have resulted from the two approaches to instruction of selected elements of descriptive geometry, were analyzed in an

TABLE II

ANALYSIS OF INITIAL STATUS OF STUDENTS BY DIFFERENTIAL TREATMENT

Control Variable	Directed Problem Analysis		Conventional Approach					
	Mean	S.D.	Mean	S.D.	M_D	SE_{DM}	df	t*
Scholastic Aptitude	53.36	10.59	51.54	8.05	1.82	2.64	50.	.68
Knowledge of Dwg. Related to Descriptive Geometry	98.61	15.84	91.25	14.78	7.36	4.27	50.	1.72
Age	19.32	1.66	19.75	1.65	.43	.46	50.	.93
Semesters of College Completed	2.18	1.39	2.58	1.77	.40	.44	50.	.92

*The t-value required for significance at .05 level is 2.01 for 50 degrees of freedom.

attempt to ascertain whether or not differences existed between the two treatment groups. Comparative data of student performance on the criterion variables appears in Appendix E.

Graphic Problem Solving Ability. A primary objective of descriptive geometry is the development of a degree of competency in the analysis and subsequent solution of graphic problems of a technical nature. An attempt was made to assess this variable by the administration of a graphic problem performance test at the conclusion of the experiment.

Since the differences of initial status between the differential treatment groups were not statistically significant with respect to each of the four selected control factors, the t-test of uncorrelated means could be applied to test the null hypothesis that no significant difference existed between the two groups with regard to graphic problem solving ability in descriptive geometry.

Following the procedure described by Guilford,[2] a preliminary investigation was made to test whether or not the variances of the two groups could possibly have arisen

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[2]Guilford, op. cit., p. 191.

by random sampling from the same population of observations, or from two populations with the same variance. The F-test was used to obtain a variance ratio. The F value of 1.12 was not significant at the five per cent level of confidence. Subsequently, a t-test of uncorrelated means was applied to the posttest mean scores for both groups. Table III shows the results of the t-test of uncorrelated means for graphic problem performance scores by differential treatment.

TABLE III

ANALYSIS OF POSTTEST GRAPHIC PROBLEM PERFORMANCE SCORES BY DIFFERENTIAL TREATMENT

Directed Problem Analysis			Conventional Approach		
Mean	=	62.11	Mean	=	57.92
SD	=	19.36	SD	=	20.45

M_D	=	4.19
SE_{DM}	=	5.53
df	=	50.
t	=	.76*

*Not significant at the .05 level.

Although the "directed problem analysis" group achieved a higher mean performance score than the "conventional approach" group, the resulting t-value of .76 was well below the table value for t at the .05 level, which was 2.01 with 50 degrees of freedom. Therefore, the null hypothesis (Ho_1) of no significant difference in graphic problem solving ability between the differential treatment groups was retained.

Spatial Perception. The capacity to visualize the space relationship of lines, points, planes, and objects is considered an essential competency possessed by the successful industrial or engineering technician. The space relations section of the *Differential Aptitude Tests* was selected to obtain a measure of this variable.

Using the t-test for uncorrelated means, initial comparisons of the pretest mean scores of the two groups revealed no significant difference in terms of spatial perception. Before testing the null hypothesis that no significant difference existed between the two groups with regard to spatial perception, it was decided to ascertain whether or not the gains in spatial perception made by the two groups were statistically significant.

The pretest and posttest mean scores for both groups were analyzed using the t-test for correlated means as described by Garrett.[3] Table IV contains the summary data of the t-test for mean pretest and posttest scores of spatial perception by differential treatment.

TABLE IV

COMPARISON OF PRETEST AND POSTTEST SCORES OF SPATIAL PERCEPTION BY DIFFERENTIAL TREATMENT

	Directed Problem Analysis		Conventional Approach	
	Pretest	Posttest	Pretest	Posttest
Mean =	47.96	52.36	48.12	53.29
SD =	10.30	7.06	9.82	8.03
M_D =	4.40		5.17	
df =	27.		23.	
t =	4.10*		4.10*	

*Significant at the .05 level.

The mean posttest spatial perception scores show similar gain over the mean pretest scores for both groups. The resulting t-value for both groups was computed to be 4.10. This value was found to be significant at the five

[3]Henry E. Garrett, Statistics in Psychology and Education (fifth edition; New York: Longmans, Green and Company, 1958), pp. 226-28.

per cent level of confidence. Both the "directed problem analysis" group and the "conventional approach" group had made statistically significant gains in spatial perception.

The next step was to ascertain whether or not there was a significant difference in the mean gain between the two groups. The results of the F test supported the assumption that the groups were not heterogeneous in variance. Hence, a t-test for the difference between uncorrelated mean gains was applied to the pretest and posttest mean scores for both groups. The summary data for the t-test of the difference between mean gains in spatial perception by differential treatment is shown in Table V.

TABLE V

ANALYSIS OF THE DIFFERENCE BETWEEN MEAN GAINS IN SPATIAL PERCEPTION BY DIFFERENTIAL TREATMENT

Directed Problem Analysis	Conventional Approach
d_m = 4.40	d_m = 5.17
Sum of d^2 = 866.67	Sum of d^2 = 875.33

SE_{DM} = 1.64

df = 50.

t = .48*

*Not significant at the .05 level.

The group of students exposed to the "conventional approach" had a slightly greater average mean gain in spatial perception than the group experiencing the "directed problem analysis" approach. However, the null hypothesis of no significant difference was accepted for Ho_2 since the resulting t-value of .48 was not significant at the five per cent level of confidence. Therefore, it was established that no significant difference existed between the two groups of students with regard to spatial perception prior to or following the differential treatments.

Abstract Reasoning Ability. The ability to reason and perceive the abstract relationships of lines, points and planes as they occupy space is considered a desirable asset to the student in the interpretation and solution of various technical problems. The assessment of this variable was obtained through the application of the abstract reasoning section of the Differential Aptitude Tests.

Using the uncorrelated means t-test, a preliminary investigation of the pretest mean scores of abstract reasoning between the two groups showed no significant difference. Prior to testing the null hypothesis that no significant difference existed between the two groups with regard to abstract reasoning ability, a decision was made to ascertain whether or not significant gains in abstract reasoning had been made by students experiencing the treatments. The t-test for correlated means was applied to the pretest and posttest mean scores for both groups; summary data for both groups are shown in Table VI.

TABLE VI

COMPARISON OF PRETEST AND POSTTEST SCORES OF ABSTRACT REASONING BY DIFFERENTIAL TREATMENT

	Directed Problem Analysis		Conventional Approach	
	Pretest	Posttest	Pretest	Posttest
Mean =	41.39	43.79	41.21	44.00
SD =	3.94	3.53	3.97	3.43
M_D =	2.40		2.79	
df =	27.		23.	
t =	3.79*		4.22*	

*Significant at the .05 level.

There was a significant increase in the mean abstract reasoning score from pretest to posttest for both the "directed problem analysis" and the "conventional approach" groups. The obtained t-value of 3.79 for the "directed problem analysis" group exceeded the table value for t at the .05 level of confidence. For those students experiencing the "conventional approach," the computed t-value was 4.22. This value was also significant at the five per cent level of confidence. Therefore, these data indicate that a significant gain in abstract reasoning had been made by both groups.

In order to test Ho_3, it was necessary to ascertain whether or not one group had made a significantly greater gain than the other group. An application of the F-test indicated that the assumption of equal variance was met for the proper application of the t-test for the difference between uncorrelated mean gains. As shown in Table VII, which contains summary data for the t-test of the difference between mean gains in abstract reasoning by differential treatment, the difference between average mean gains on the abstract reasoning tests was slight. The resulting t-value of .44 was not significant at the five per cent level of confidence.

Since no initial difference existed between the groups on this variable, this test was considered as an appropriate basis for accepting the null hypothesis (Ho_3) of no significant difference between average mean gains in abstract reasoning between students experiencing the differential treatments.

TABLE VII

ANALYSIS OF THE DIFFERENCE BETWEEN MEAN GAINS IN ABSTRACT REASONING BY DIFFERENTIAL TREATMENT

Directed Problem Analysis		Conventional Approach	
d_m	= 2.40	d_m	= 2.79
Sum of d^2	= 300.68	Sum of d^2	= 241.95

SE_{DM} = .91

df = 50.

t = .44*

*Not significant at the .05 level.

Informational Achievement. Technical information, as defined in this study, refers to information related to the principles, techniques and terminology of descriptive geometry. Since no standardized tests were available to measure this variable, an objective-type test was developed by the investigator and administered to both groups at the completion of the experiment.

An application of the F-test revealed that the assumption of homogeneity of variance had been met for the proper application of the t-test of uncorrelated means. Hence, the null hypothesis that no significant difference existed between the two groups with regard to informational achievement in descriptive geometry was tested by application of the uncorrelated means t-test to the posttest informational achievement scores of the total research population. The summary data for the t-test of mean informational achievement scores by differential treatment is reported in Table VIII.

TABLE VIII

ANALYSIS OF POSTTEST INFORMATIONAL ACHIEVEMENT SCORES BY DIFFERENTIAL TREATMENT

Directed Problem Analysis			Conventional Approach		
Mean	=	78.39	Mean	=	76.83
SD	=	10.82	SD	=	11.14

M_D	=	1.56
SE_{DM}	=	3.05
df	=	50.
t	=	.51*

*Not significant at the .05 level.

Students experiencing the "directed problem analysis" approach attained a slightly greater mean informational achievement score than the group exposed to the "conventional approach." However, the computed t-value of .51 was less than the table value for t at the five per cent level of confidence. On the basis of this test the null hypothesis (Ho_4) of no significant difference in informational achievement between the differential treatment groups was accepted.

Student Attitude Toward the Course. The assessment of student attitude toward descriptive geometry for this study had a two-fold purpose: (1) to ascertain whether or not a significant change in attitude toward the course had occurred for each group during treatment, and (2) to ascertain whether or not significant differences in attitude toward descriptive geometry existed between students experiencing the treatments. Remmers' Scale for Measuring Attitude Toward Any School Subject, Forms A and B were used to secure a measure of initial and final student attitude toward descriptive geometry.

A t-test of uncorrelated means revealed no significant difference between the mean scores of the two groups on the attitude pretest. In an attempt to ascertain whether or not a significant change in attitude toward descriptive geometry had taken place by students experiencing the differential treatments, the t-test for correlated means was applied to the pretest and posttest mean attitude scores for both groups. The analysis of pretest and posttest mean attitude scores by differential treatment is reported in Table IX.

TABLE IX

COMPARISON OF PRETEST AND POSTTEST SCORES OF ATTITUDE TOWARD DESCRIPTIVE GEOMETRY BY DIFFERENTIAL TREATMENT

	Directed Problem Analysis		Conventional Approach	
	Pretest	Posttest	Pretest	Posttest
Mean =	7.99	7.72	8.12	7.82
SD =	.474	.968	.485	.627
M_D =	-.27		-.30	
df =	27.		23.	
t =	1.16		2.12*	

*Significant at the .05 level.

The mean attitude scores for the "directed problem analysis" group and the "conventional approach" group decreased slightly from pretest to posttest. The computed t-value for students experiencing the "directed problem analysis" approach was 1.16. This value was not significant at the five per cent level of confidence, thus indicating that the attitude toward descriptive geometry of the "directed problem analysis" group had not changed significantly during the experiment.

In contrast, the obtained t-value of 2.12 for the students who experienced the "conventional approach" was significant at the five per cent level of confidence. The attitude toward descriptive geometry of the "conventional approach" group was significantly lower at the conclusion of the experiment.

The attitude toward descriptive geometry of students experiencing the two approaches remained positive at the conclusion of the experiment, since posttest mean scores for both groups exceeded 6.0, the point of "indifference" on the scale.

Application of the F-test for homogeneity of variance produced an F ratio which was significant at the five per cent level of confidence. Guilford[4] recommends the Cochran and Cox test as a statistical method of meeting the case of unequal variances. Therefore, in order to test the null hypothesis that no significant difference existed between the two groups in terms of attitude toward descriptive geometry, a Cochran-Cox t-test was calculated for the difference between mean gains of attitude pretest and posttest scores. The summary data for the Cochran-Cox

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[4]Guilford, op. cit., p. 185.

t-test of the difference between mean gains in attitude toward the course by differential treatments appears in Table X.

TABLE X

ANALYSIS OF THE DIFFERENCE BETWEEN MEAN GAINS IN ATTITUDE TOWARD THE COURSE BY DIFFERENTIAL TREATMENT

Directed Problem Analysis			Conventional Approach		
d_m	=	-.27	d_m	=	-.30
Sum of d^2	=	39.064	Sum of d^2	=	11.310

SE_{DM}	=	.2682
df	=	27. and 23.
Cochran-Cox t_o	=	.15*

*Not significant at the .05 level.

Although the group which experienced the "conventional approach" had a significant decrease in attitude toward the course from mean pretest to posttest scores, the resulting Cochran-Cox t-value of .15 did not exceed the table values for t at .05 using 27 and 23 degrees of freedom. Hence, the null hypothesis (Ho_5) of no significant difference in attitude toward descriptive geometry between the differential treatment groups was accepted.

Also, no initial differences existed between the attitudes toward descriptive geometry of students who experienced the two instructional approaches.

Comparison and Analysis of the Retention of Students

Data from the total research population were analyzed to ascertain whether or not differences in retention existed between the two groups experiencing instruction in descriptive geometry by the two different approaches. Comparative data of student performance on tests of retention involving graphic problem performance and informational achievement appears in Appendix E.

Graphic Problem Solving Ability. In order to ascertain the retention of students, in terms of graphic problem solving ability, alternate forms of a graphic problem performance test were administered to both groups three weeks after the completion of the experiment. These tests were similar, but not identical to the tests used to measure graphic problem solving ability immediately after treatment.

The mean scores of the two groups for the posttest and retention test were analyzed using the t-test for correlated means. This analysis was made in an attempt to assess whether or not significant changes had taken place with regard to the students' ability to solve graphic problems in descriptive geometry three weeks after receiving instruction. Table XI shows the analysis of posttest and retention test mean performance scores by differential treatment.

TABLE XI

COMPARISON OF POSTTEST AND RETENTION TEST SCORES OF GRAPHIC PROBLEM PERFORMANCE BY DIFFERENTIAL TREATMENT

	Directed Problem Analysis		Conventional Approach	
	Posttest	Retention Test	Posttest	Retention Test
Mean =	62.21	64.07	65.91	59.00
SD =	24.76	21.45	26.25	21.08
M_D =	1.86		-6.91	
df =	27.		21.**	
t =	.50*		1.63*	

*Not significant at the .05 level.

**The N decreased from 24 to 22.

The "directed problem analysis" group demonstrated a slight gain while the "conventional approach" group exhibited a decrease in the mean graphic problem performance score from posttest to retention test. However, these differences were not in excess of the table value for t at

.05 as reported in Table XI.

This evidence indicated that neither of the two treatment groups had a significantly superior mean retention score, in terms of graphic problem solving ability, when measured three weeks after treatment.

Application of the F-test indicated that homogeneity of variance existed; therefore, the t-test for the difference between uncorrelated mean gains could be employed to test the null hypothesis that no significant difference existed between the two groups with regard to retention, in terms of graphic problem solving ability. In Table XII, an analysis of the application of the t-test for retention of graphic problem solving ability by differential treatment is reported.

The group which experienced the "directed problem analysis" approach demonstrated a slight average mean gain with regard to graphic problem solving ability between the posttest and the retention test, while the group exposed to the "conventional approach" evidenced a substantial decrease on this variable. However, the computed t-value of 1.59 indicated that the difference between the groups with regard to retention scores was not significant at the five per cent level of confidence. Hence, the null hypothesis (Ho_6) of no significant difference between the retention of graphic problem solving ability by students who experienced the differential treatments was accepted.

TABLE XII

ANALYSIS OF THE DIFFERENCE BETWEEN MEAN GAINS ON THE RETENTION TEST OF GRAPHIC PROBLEM PERFORMANCE BY DIFFERENTIAL TREATMENT

Directed Problem Analysis		Conventional Approach	
d_m	= 1.86	d_m	= -6.91
Sum of d^2	= 10,469.71	Sum of d^2	= 8,301.82

SE_{DM} = 5.50

df = 48.

t = 1.59*

*Not significant at the .05 level.

Informational Achievement. An attempt was made to obtain a measure of the retention of informational content by students three weeks after experiencing the differential treatments. The same instrument was used for the test of retention as had been used for the posttest of informational achievement.

An initial attempt was made to ascertain whether or not students who had been exposed to the differential treatments demonstrated a capacity to retain related technical information in descriptive geometry. The mean scores for the posttest and retention test taken by both groups were analyzed using the t-test for correlated means. The analysis of posttest and retention test mean scores for informational achievement by differential treatment appears in Table XIII.

TABLE XIII

COMPARISON OF POSTTEST AND RETENTION TEST SCORES OF INFORMATIONAL ACHIEVEMENT BY DIFFERENTIAL TREATMENT

	Directed Problem Analysis		Conventional Approach	
	Posttest	Retention Test	Posttest	Retention Test
Mean =	78.39	78.75	77.27	77.95
SD =	10.62	11.16	10.79	7.48
M_D =	.36		.68	
df =	27.		21.**	
t =	.26*		.43*	

*Not significant at the .05 level.

**The N decreased from 24 to 22.

There was a slight increase in the mean informational achievement score from posttest to retention test for both the "directed problem analysis" and the "conventional approach" groups; however, as indicated in Table XIII, these differences were not significant at the .05 level of confidence.

In order to test the null hypothesis that no significant difference existed between the informational achievement retention test scores of students who had experienced instruction by the two approaches, the t-test for the difference between uncorrelated mean gains was employed. This test was appropriate since the application of the F-test revealed that the assumption of homogeneity of variances had been satisfied. Summary data of the t-test for the retention of technical information in descriptive geometry by differential treatment is shown in Table XIV.

TABLE XIV

ANALYSIS OF THE DIFFERENCE BETWEEN MEAN GAINS ON THE RETENTION TEST OF INFORMATIONAL ACHIEVEMENT BY DIFFERENTIAL TREATMENT

Directed Problem Analysis	Conventional Approach
d_m = .36	d_m = .68
Sum of d^2 = 1,399.99	Sum of d^2 = 1,142.98

SE_{DM} = 2.08

df = 48.

t = .16*

*Not significant at the .05 level.

Although the "conventional approach" group evidenced a slightly greater average mean gain than the "directed problem analysis" group, the resulting t-value of .16 was not in excess of the table value for t at the five per cent level of confidence. The null hypothesis (Ho_7) of no significant difference between the retention of informational content by students who experienced instruction by the two approaches was accepted.

Summary

Data obtained from the total research population were analyzed to ascertain whether or not initial differences existed between the two treatment groups. The primary factors chosen for ascertaining the initial status of the groups were: (1) scholastic aptitude, and (2) knowledge of drawing related to descriptive geometry. Additional initial data were secured for the factors of age and semesters of college work completed.

The t-test for uncorrelated means indicated that no significant differences existed between the two groups with respect to scholastic aptitude, knowledge of drawing related to descriptive geometry, age, or semesters of college work completed.

Examinations developed by the investigator were used to obtain a final measure of graphic problem solving ability and informational achievement. The space relations and abstract reasoning sections of the Differential Aptitude Tests were selected to obtain initial and final measures of spatial perception and abstract reasoning ability. The Forms A and B of Remmers' Scale for Measuring Attitude Toward Any School Subject were used to secure a measure of initial and final student attitude toward descriptive geometry.

Application of the t-test for uncorrelated means to the posttest results required the acceptance of the null hypothesis of no significant difference between the two groups with regard to graphic problem solving ability and informational achievement. Null hypotheses Ho_1 and Ho_4 were accepted as tenable on the basis of these findings.

Using the t-test for uncorrelated means, initial comparisons of pretest mean scores for the two groups revealed no significant differences in terms of spatial perception, abstract reasoning ability, and student attitude toward the course. Application of the t-test for correlated means indicated that both treatment groups had made significant gains in spatial perception and abstract reasoning ability during the experiment. The "conventional approach" group was found to have a significantly lower attitude toward descriptive geometry at the conclusion of the experiment. The "directed problem analysis" group also evidenced a change in attitude, but the change was found not to be significant. However, the attitude toward the course of both groups had remained favorable.

The t-test for the difference between uncorrelated mean gains was employed to test for differences between the two groups in terms of spatial perception and abstract reasoning ability. The null hypotheses Ho_2 and Ho_3 were accepted as defensible since no significant differences were found between the two groups on spatial perception and abstract reasoning. Application of the Cochran-Cox t-test indicated no significant difference between the treatment groups with regard to attitude toward descriptive geometry; thus, the null hypothesis Ho_5 was accepted.

When data relating to the retention of students were analyzed, the "directed problem analysis" group demonstrated a slight mean gain in graphic problem solving ability while the "conventional approach" group evidenced a substantial decrease on this variable. However, the t-test of the difference between uncorrelated mean gains indicated no significant difference between the retention of the two groups with respect to graphic problem solving ability. No significant difference was found between the retention of the treatment groups in terms of informational achievement. These findings led to the acceptance of null hypotheses Ho_6 and Ho_7.

On the basis of the findings of this study, the research hypotheses that: (1) selected elements of descriptive geometry could be taught more effectively, in terms of student behavioral changes, by the directed problem analysis approach, and (2) the retention of selected elements of descriptive geometry would be superior for students experiencing the directed problem analysis approach, were rejected.

CHAPTER V

SUMMARY, CONCLUSIONS, IMPLICATIONS, AND PROBLEMS FOR FURTHER STUDY

The purpose of this study was to ascertain whether or not students who had received instruction in descriptive geometry by a directed problem analysis approach were able to attain significantly greater levels of competence than students who had received instruction by a more conventional approach.

More specifically, the study sought answers to the following questions:

1. Do the instructional approaches significantly affect student performance in the solution of graphical problems in descriptive geometry?

2. Do the instructional approaches significantly affect student ability to visualize spatial relationships?

3. Do the instructional approaches significantly affect student ability to reason abstractly?

4. Do the instructional approaches significantly affect student achievement relative to technical information in descriptive geometry?

5. Do the instructional approaches significantly affect student attitude toward the course?

The research hypotheses under consideration in this study were: (1) that selected elements of descriptive geometry could be taught more effectively, in terms of student behavioral changes, by the directed problem analysis approach, and (2) that the retention of selected elements of descriptive geometry would be superior for students experiencing the directed problem analysis approach than for those experiencing a more traditional approach.

The first research hypothesis was tested by accepting or rejecting the following null hypotheses:

Ho_1: No significant difference exists between the graphic problem solving ability of students who experience the directed problem analysis approach and the graphic problem solving ability of students who experience the conventional approach.

Ho_2: No significant difference exists between the spatial perception of students who experience the directed problem analysis approach and the spatial perception of students who experience the conventional approach.

Ho_3: No significant difference exists between the abstract reasoning ability of students who experience the directed problem analysis approach and the abstract reasoning ability of students who experience the conventional approach.

Ho_4: No significant difference exists between informational achievement of students who experience the directed problem analysis approach and the informational achievement of students who experience the conventional approach.

Ho_5: No significant difference exists between the attitude toward the course of students who experience the directed problem analysis approach and the attitude toward the course of students who experience the conventional approach.

The second research hypothesis was tested by accepting or rejecting the following null hypotheses:

Ho_6: No significant difference exists between the retention, in terms of graphic problem solving ability, of students who experience the directed problem analysis approach and the retention of students who experience the conventional approach as measured three weeks after treatment.

Ho_7: No significant difference exists between the retention of cognitive content of students who experience the directed problem analysis approach and the retention of students who experience the conventional approach as measured three weeks after treatment.

The study was conducted as a controlled experiment involving two groups of students enrolled in ME 10 Descriptive Geometry in the Department of Mechanical Engineering, University of Missouri - Columbia.

The researcher acted in a coordinating capacity during the course of the investigation, but was not directly involved in teaching either of the two treatment groups. Students registered for the course and were assigned to the sections according to the availability of space. The differential treatments were randomly assigned to the sections and the experimental period was limited to eight weeks. The research procedure followed was to pretest the groups, apply the treatments to the groups, and posttest to ascertain the effects of the treatments. Measures of retention were secured for the total research population three weeks after treatment. Appropriate variations of the t-test were the statistical techniques utilized in testing the null hypotheses.

Summary

In this two-group controlled experiment a quasi-experimental research design was employed in the comparison of the relative effectiveness of two approaches to the teaching of selected elements of descriptive geometry. All factors with the exception of the selected laboratory approaches to teaching descriptive geometry were held constant or controlled insofar as was possible.

The two approaches to teaching selected elements of descriptive geometry used in this study were the "directed problem analysis approach" (Approach A) and the "conventional approach" (Approach B).

The population participating in the study included fifty-two students enrolled in two sections of ME 10 Descriptive Geometry, a course offered in the College of

Engineering at the University of Missouri - Columbia during the fall semester of the 1967-1968 school year. There were twenty-eight students included in the section which utilized Approach A (directed problem analysis) and twenty-four students were in the section which employed Approach B (the conventional approach).

The instructional content of ME 10 Descriptive Geometry was considered to be representative of a basic course in this subject. The textbook, homework and laboratory work sheets, laboratory schedule, composite outline by period, and homework assignment sheets were identical for both groups. In addition, both sections were taught by the same instructor.

All students included in the study received their instruction in the same laboratory, had access to similar equipment, and attended the same one-hour weekly lectures. The physical facilities utilized in the experiment were equal for both sections, insofar as the researcher could ascertain.

This study was an attempt to compare the relative effectiveness of two approaches to teaching selected elements of descriptive geometry. Assessment was accomplished through a comparison of the following student behavioral variables: (1) performance in the solution of graphical problems, (2) spatial perception, (3) abstract reasoning ability, (4) technical information achievement, and (5) student attitude toward descriptive geometry.

It was essential to test for the initial status of both groups before any differences in results could be attributed to the differential treatments. The primary factors selected for ascertaining initial status of the groups were: (1) scholastic aptitude, and (2) knowledge of drawing related to descriptive geometry. Additional data relative to the factors of age and semesters of college work completed were secured. Initial measures were also obtained for the criterion variables of spatial perception, abstract reasoning, and attitude toward descriptive geometry.

The several standardized instruments utilized to measure scholastic aptitude, knowledge of drawing related to descriptive geometry, and attitude toward the course were the Cooperative School and College Ability Test (SCAT), Blum's Comprehensive General Drafting Examination, and Remmers' Scale for Measuring Attitude Toward Any School Subject. The space relations and the abstract reasoning sections of the Differential Aptitude Tests (DAT), Form L, were used to obtain a measure of spatial perception and abstract reasoning ability. Data regarding the students' age and semesters of college work completed were secured from an information form included as a part of the attitude scale answer sheet. Accuracy of this information was verified by a random check of the student's permanent records and of student information forms on file with the engineering graphics supervisor.

Since no applicable standardized tests were available, the criterion variables of graphic problem solving ability and informational achievement required the use of teacher-constructed examinations. A panel of three experienced teachers of descriptive geometry judged both examinations to be valid.

The objective-type of informational achievement test exhibited a reliability index of .96 for the combined groups. The laboratory instructor administered the tests of graphic problem performance and informational achievement at the close of the experimental period.

In an attempt to obtain a measure of retention in terms of technical information, the same informational achievement test was readministered to both groups three weeks after treatment. At an interval of three weeks following the treatment, a test similar, but not identical to the posttest of performance was administered to both groups to ascertain the degree of retention on this variable. Validation procedures for the retention test were identical to those applied to the posttest of performance. Both the posttests and retention tests of performance were evaluated by three experienced drafting instructors at the University of Missouri - Columbia. The investigator, aided by an instructor of drafting at the University, evaluated the posttests and retention tests of informational achievement.

All other examinations and quizzes were administered under the supervision of the investigator or the laboratory instructor of descriptive geometry with the exception of the Cooperative School and College Ability Test, which was administered and scored by the Testing and Counseling Service of the University of Missouri - Columbia.

A composite outline and a homework assignment schedule were provided to each student in order to minimize instructional differences. All laboratory assignments, quizzes and major examinations were set forth in a detailed laboratory schedule to further insure uniformity in the presentation of instructional content. An experienced professor of engineering graphics conducted the weekly common lectures which were supplemented with a comprehensive series of correlated film slides.

The laboratory experiences of both groups were supervised by an experienced instructor. The investigator worked closely with the instructor and supervisor of engineering graphics to insure proper implementation of the differential treatments.

Students who were exposed to the "directed problem analysis" approach attempted to identify and order, in writing, the constituent factors inherent in the assigned problems prior to attempting accurate solutions. Simple illustrative sketches of tentative solutions were encouraged to supplement the analysis procedure.

In the section employing the "conventional approach" students attempted accurate solutions to the problems under consideration without the aid of a preliminary, structured, written or graphical analysis.

Students in both groups were held responsible for all lecture information, discussion, and assigned readings. Both groups were assigned identical laboratory problems and these were graded using a uniform marking system. The regular instructional program called for the administration of one unit examination and several quizzes during the experimental period.

Records maintained by the experimenter included the attendance of all students as well as grades on required quizzes, major examinations, and required laboratory assignments.

Data obtained from the total research population were analyzed to ascertain whether or not initial differences existed between the two groups. Scholastic aptitude and knowledge of drawing related to descriptive geometry were the primary factors chosen for ascertaining the initial status of the groups. Initial data were also secured for the factors of age and semesters of college work completed.

The t-test for uncorrelated means indicated that no significant differences existed between the two groups with respect to scholastic aptitude, knowledge of drawing related to descriptive geometry, age, or semesters of college work completed.

Examinations developed by the investigator were used to obtain final and retention measures of graphic problem solving ability and informational achievement. Initial and final measures of spatial perception, abstract reasoning ability, and student attitude toward descriptive geometry were secured through application of the space relations and abstract reasoning sections of the *Differential Aptitude Tests* and *Forms A and B* of Remmers' *Scale for Measuring Attitude Toward Any School Subject*.

The differences between the two instructional approaches, with regard to the criterion variables of graphic problem solving ability and informational achievement, were ascertained through application of the t-test for uncorrelated means. The null hypothesis of no significant differences between the two approaches was accepted with regard to the graphic problem solving ability and the informational achievement of the total research population of the study. Null hypotheses Ho_1 and Ho_4 were accepted on the basis of these findings.

Utilizing the t-test for uncorrelated means, initial comparisons of pretest mean scores for the two groups revealed no significant differences with respect to spatial perception, abstract reasoning ability, and student attitude toward the course. The t-test for correlated means indicated that both treatment groups had made significant gains in spatial perception and abstract reasoning ability during the experiment. At the conclusion of the experiment, the "conventional approach" group exhibited a significantly lower attitude toward descriptive geometry. Although the "directed problem analysis" group also evidenced a change in attitude, the change was found not to be significant. The attitude toward the course of both groups had remained favorable.

A t-test for the difference between uncorrelated mean gains indicated no significant differences between the two groups in terms of spatial perception and abstract reasoning. Hence, the null hypotheses Ho_2 and Ho_3 were accepted. Application of the Cochran-Cox t-test indicated no significant difference between the treatment groups with regard to attitude toward descriptive geometry; thus, the null hypothesis Ho_5 was retained.

When data relating to the retention of students were analyzed, the "directed problem analysis" group demonstrated a slight average mean gain in graphic problem solving ability while the "conventional approach" group evidenced a substantial decrease on this variable. Both groups evidenced a slight increase in the mean informational achievement score from posttest to retention test. However, the t-test of the difference between uncorrelated mean gains indicated no significant differences between the retention of the two groups with regard to graphic problem solving ability and informational achievement. These findings led to the acceptance of null hypotheses Ho_6 and Ho_7.

On the basis of the findings of this study, the research hypotheses that: (1) selected elements of descriptive geometry could be taught more effectively, in terms of student behavioral changes, by the directed problem analysis approach, and (2) the retention of selected elements of descriptive geometry would be superior for students experiencing the directed problem analysis approach, were rejected.

Conclusions

To the extent that the data and findings resulting from the research procedure employed in this study are valid and representative of descriptive geometry students on the college level, the following conclusions may be drawn:

An approach to teaching selected elements of descriptive geometry which would contribute to the development of significantly superior graphic problem solving ability has not emerged from either of the two approaches employed in this investigation.

Both approaches to teaching selected elements of descriptive geometry resulted in significant gain in spatial perception and abstract reasoning ability by the students. Therefore, either approach could be expected to provide an opportunity for college level students in descriptive geometry to improve their spatial perception and abstract reasoning ability.

The two approaches to teaching selected elements of descriptive geometry resulted in similar gain in informational achievement by the students included in this study. Hence, it appears that either approach would be equally effective in promoting the informational achievement of college level descriptive geometry students.

Although the "conventional approach" evidenced a significantly lower attitude toward the course at the conclusion of the experiment than initially, students in both treatment groups maintained a favorable attitude toward descriptive geometry. Neither of the laboratory approaches investigated in the study appears to be more effective than the other in terms of influencing student attitude toward descriptive geometry.

The "directed problem analysis" approach produced a slight mean gain in graphic problem solving ability, whereas the "conventional approach" evidenced a decrease on this variable from posttest to retention test. However, the study failed to reveal a significantly superior approach for improving student retention with regard to the ability to solve graphic problems in descriptive geometry.

Neither of the two laboratory approaches explored in this study appears to be more effective than the other in terms of increasing student competency to retain technical information content in descriptive geometry.

Since the observed student behavioral changes and the retention of selected elements of descriptive geometry were not significantly affected by the instructional approach, neither of the two approaches to teaching selected elements of descriptive geometry, as presented in this investigation, is judged to be superior to the other.

Inasmuch as both approaches investigated in the study contributed positively to student achievement, drafting instructors need not hesitate to use either approach in the teaching of descriptive geometry.

Implications

In view of the findings and conclusions of this study, the following implications appear to be in order:

Since student attitude and the retention of graphic problem solving ability were affected positively by the "directed problem analysis" approach, and since the decrease in attitude between pretest and posttest was not significant, instructors of descriptive geometry may wish to make increased use of this laboratory approach in their classes.

Since neither of the approaches explored in the study was found to produce superior student achievement, additional research should be undertaken in an effort to identify, compare, and evaluate the relative effectiveness of other instructional approaches in descriptive geometry.

Authors, publishers, and supervisors of engineering graphics programs in schools and colleges may wish to advocate increased use of the "directed problem analysis" approach since it appears to be as effective as the "conventional approach" now employed by many instructors in the field.

Descriptive geometry teachers, department heads, authors and publishers may wish to produce completed analyses of graphic problems presented in textbooks and workbooks as an aid to classroom instruction.

Although the "directed problem analysis" approach did not result in superior student behavioral changes or retention in descriptive geometry, it might be well to apply this approach in other disciplines to facilitate observation of its affect on student achievement.

Problems for Further Study

During the course of this study, a number of related problems of sufficient merit to warrant investigation presented themselves. They are as follows:

1. What approach to teaching descriptive geometry

would be most effective for technical school students? Junior college students? Vocational school students? High school students?

2. Would a replication of this study with a longer period devoted to investigation result in significant differences in terms of student behavioral changes and retention? With a larger research population? With more and/or different descriptive geometry principles?

3. Can a standardized performance test be developed in descriptive geometry with a reasonable time allowance for administration and evaluation? A technical information test?

4. Would a problem analysis approach influence student achievement in a beginning drafting course?

5. What approach to teaching descriptive geometry would result in optimum utilization of time required to solve graphic problems?

6. What approach to teaching descriptive geometry would be most effective for students with varying degrees of ability?

7. Would an integrated course in engineering drawing and descriptive geometry be more effective with regard to student behavioral changes, than a separate course in descriptive geometry?

8. Would unsupervised laboratory periods rather than the controlled laboratory be more effective in teaching descriptive geometry?

9. What factors within the approach to teaching descriptive geometry influence student retention?

10. What elements in a course cause a change in student attitude from pretest to posttest?

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APPENDIX A

Test for Knowledge of Drawing Related to Descriptive Geometry

Attitude Scales

Attitude Scale Answer Sheet and Student Information Form

Differential Aptitude Tests

GENERAL DRAFTING

A COMPREHENSIVE EXAMINATION

Copyright 1964

Robert E. Blum

EXAMINATION NO. 002050

DIRECTIONS

The purpose of this test is to measure your knowledge in the area of general drafting.

Complete the following information in the heading on the left side of the answer sheet:

1. Name
2. Date
3. School
4. Examination number (Write this in the space labeled "Name of Test")
5. Starting time (Write this in blank "1" below "School" just before beginning)
6. Finishing time (Write this in blank "2" below "City" when you turn-in your materials). If you take the examination in two sessions, write starting and finishing times for each session.

All answers should be marked with the special pencil provided. Indicate your choice by darkening the area between the parallel lines in the appropriate answer column. If an answer must be changed, erase completely and re-mark the item. Do not make any extra marks on the answer sheet, as they will affect your score.

This examination consists of three similar types of items. An example of each follows:

1. Information Items. Read these items carefully and select the best answer.

EXAMPLE: 1. The instrument used to draw circles is:

a. an irregular curve. c. a protractor.

b. a compass. d. none of these.

SAMPLE ANSWER: 1. a ‖ b ▮ c ‖ d ‖

Interpret the answer, "none of these", to mean that the correct answer is not listed as a possible choice.

2. Illustration Items. Read the item and study the appropriate illustration. Select the best answer and indicate your choice.

EXAMPLE: 2. The drawing in figure E2 is:

a. a correct pictorial representation of a cylinder.

b. a correct sectional view of a cylinder.

c. a correct orthographic projection of a cylinder.

d. not a correct representation of a cylinder.

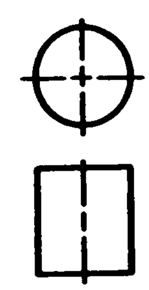
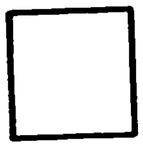


Figure E2

SAMPLE ANSWER: 2. a ‖ b ‖ c ▮ d ‖

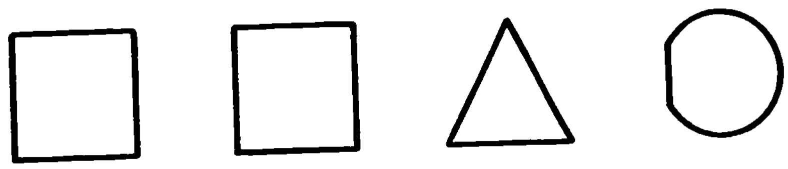
3. <u>Visualization Items</u>. Read the item and select the best answer from a series of illustrations.

EXAMPLE:



3. The correct right side view of the object shown is:

a. b. c. d. none of these.



SAMPLE ANSWER: 3. a ▮ b || c || d ||

<u>Please do not mark on the examination</u>

Work as rapidly as possible, but read each item carefully before answering. Do not spend too much time on any one item. Answer the items to the best of your ability, but DO NOT GUESS. The score will be computed with a correction for guessing, the number right minus the number wrong divided by three.

When the examination has been completed, write the finishing time in blank "2" in the heading on the answer sheet, be sure that the information on the answer sheet is complete, and hand the examination and the answer sheet to the test administrator.

The examination consists of two parts, each of which includes several sub-tests. If you are taking the examination in one double period testing session, complete the entire examination without stopping. If you are taking the examination in two single period testing sessions, complete part 1, 66 items, during the first session and part 2, 74 items, during the second session. The entire examination includes 140 items.

Write the starting time in blank "1" below "School" in the heading and begin when you are told to do so.

Drawing Equipment and Material

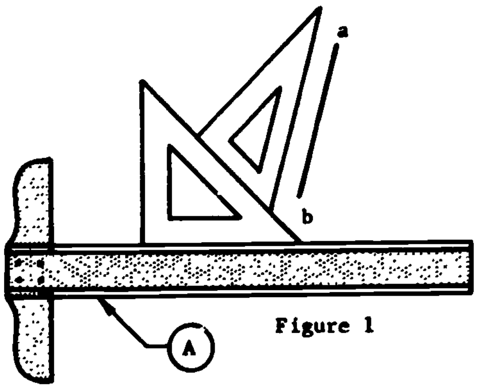
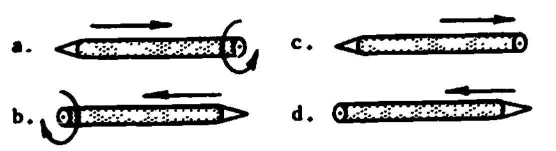


Figure 1

1. If you are right-handed, instrument (A) shown in figure 1 should be manipulated with:
   - a. either hand.
   - b. your right hand.
   - c. your left hand.
   - d. both hands.

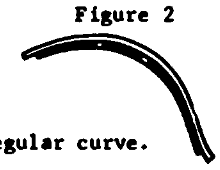
2. If you are right-handed and using a pencil with a conical point, the proper way to draw a horizontal line is:



3. By using the equipment shown in figure 1 in various combinations, angles can be drawn in increments of:
   - a. 45°
   - b. 30°
   - c. 15°
   - d. 5°

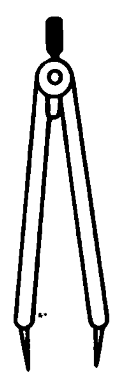
4. From the horizontal, line ab in figure 1 is:
   - a. 75°
   - b. 95°
   - c. 120°
   - d. 125°

Figure 2



5. The piece of equipment shown in figure 2 is designed to perform the same tasks as:
   - a. an ellipse guide.
   - b. a compass.
   - c. an irregular curve.
   - d. none of these.

Figure 3



6. A primary use of the instrument shown in figure 3 is:
   - a. transferring measurements from a scale to a drawing.
   - b. transferring measurements from place to place on a drawing.
   - c. drawing circles and arcs.
   - d. none of these.

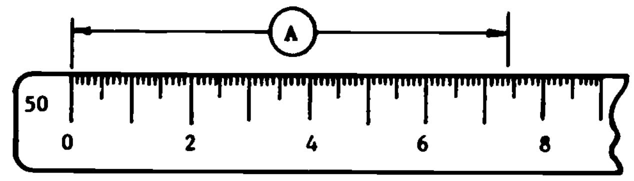


Figure 4

7. Using a scale of 1" = 50', Distance (A) in figure 4 equals:
   - a. 69'.
   - b. 74'.
   - c. 79'.
   - d. none of these.

8. Most industrial drawings today are:
   - a. made in pencil on drawing paper.
   - b. made in pencil on drawing paper and traced in ink on tracing paper, tracing cloth or polyester.
   - c. made in pencil on tracing paper, tracing cloth or polyester and then inked.
   - d. made in pencil directly on tracing paper, tracing cloth or polyester.

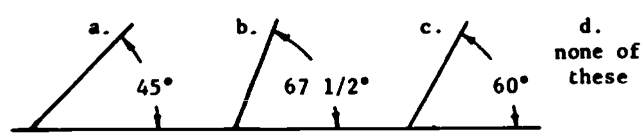
Lettering

9. Upper case letters on working drawings are commonly:
   - a. 3/32" high.
   - b. 1/16" high.
   - c. 1/8" high.
   - d. 5/16" high.

10. American Standard lettering looks like:
    - a. And
    - b. *And*
    - c. And
    - d. none of these.

11. The relationship of fractions to whole numbers should be:

12. The recommended angle for inclined lettering is:



13. The American Standards call for:
    - a. vertical lettering only.
    - b. inclined lettering only.
    - c. vertical or inclined lettering.
    - d. a mixture of vertical and inclined lettering.

14. The general rule for spacing letters within a word is:

    a. the distance between letters should be equal.

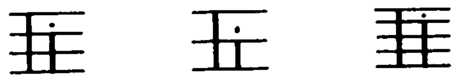
    b. the distance between letters should be as large as a zero.

    c. the area between letters should cover about one-fourth as much area as the preceding letter.

    d. the areas between letters should be about equal.

15. The relationship of lower case letters to upper case letters should be:

    a. b. c. d. None of these.



16. The space between words should be about as large as the letter:

    a. U. c. O.

    b. W. d. none of these.

17. The numbers along the bottom of the guide line device shown in figure 5 indicate:

    a. 1/32". c. 1/8".

    b. 1/16". d. none of these.

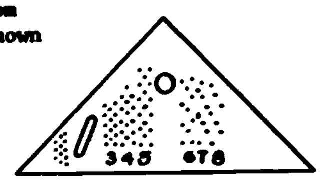


Figure 5

Applied Geometry

18. A hexagon has:

    a. five sides. c. eight sides.

    b. six sides. d. ten sides.

19. The construction shown in figure 6 is a solution to the problem of:

    a. drawing an arc of radius r tangent to lines AB and CD.

    b. drawing an arc of radius r tangent to line AB only.

    c. drawing an arc of radius r tangent to line CD only.

    d. none of these.

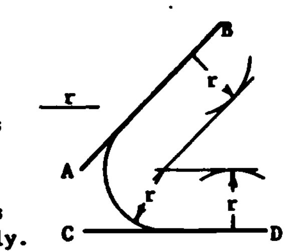


Figure 6

20. The construction shown in figure 7 is preliminary to the completion of:

    a. a pentagon.

    b. a nonagon.

    c. an octagon.

    d. a hexagon.

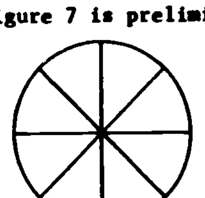


Figure 7

21. The construction shown in figure 8 is a solution to the problem of:

    a. drawing lines parallel to AB.

    b. dividing line AC into a number of equal parts.

    c. dividing line AB into a number of equal parts.

    d. none of these.

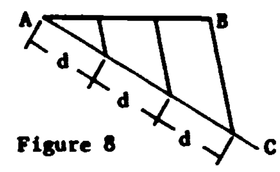


Figure 8

22. The object shown in figure 9 is:

    a. an octagon.

    b. a pentagon.

    c. a decagon.

    d. none of these.

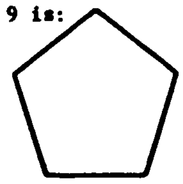


Figure 9

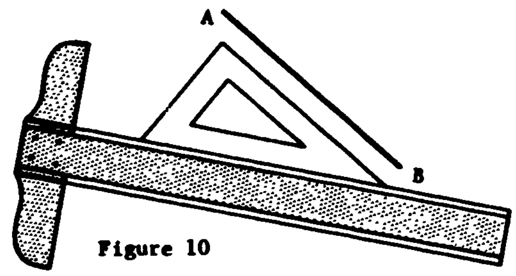


Figure 10

23. The set-up shown in figure 10 is used for drawing lines:

    a. parallel to line AB.

    b. perpendicular to line AB.

    c. either parallel or perpendicular to line AB.

    d. none of these.

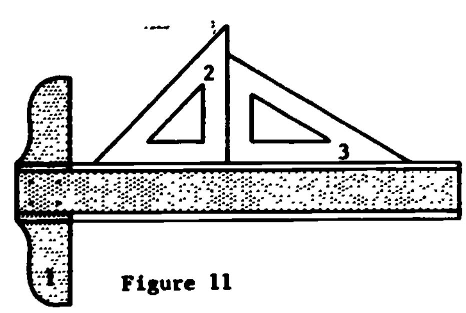


Figure 11

24. The combination of instruments shown in figure 11 used to construct a hexagon is:

    a. 1 and 2. c. 2 and 3.

    b. 1 and 3. d. none of these.

25. The construction shown in figure 12 is a solution to the problem of:

    a. bisecting line AB

    b. constructing a right triangle from three given sides.

    c. constructing a perpendicular to line AB.

    d. none of these.

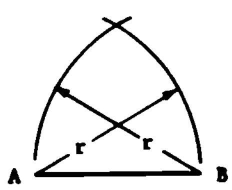


Figure 12

26. An ellipse drawn by the method shown in figure 13 is:

a. a true ellipse.

b. an approximation of a true ellipse.

c. longer than a true ellipse.

d. like an ellipse drawn with an ellipse guide.

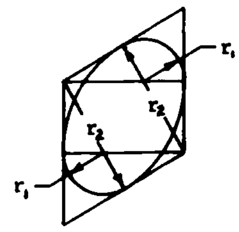


Figure 13

27. The method of drawing an ellipse shown in figure 13 is:

a. the concentric circle method.

b. the trammel method.

c. the axes method.

d. the approximate four-center method.

28. The construction shown in figure 14 is a complete solution to the problem of:

a. constructing an angle equal to a given angle.

b. constructing a right triangle with a given side and hypotenuse.

c. constructing a triangle from three given sides.

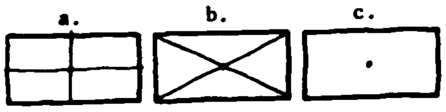
d. the construction is not complete.


Figure 14

Sketching

29. The most accurate way of estimating the center of a rectangle is:

a. b. c. d. none of these



30. The center lines shown in the sketch in figure 15 are:

a. the correct weight.

b. too thick.

c. too thin.

d. weight is unimportant in sketching.

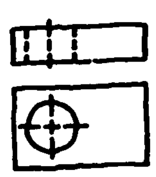


Figure 15

31. The most important consideration in sketching listed below is:

a. exactness of measurements.

b. proportion of the object.

c. straightness of lines.

d. quality of line work.

32. When first sketching a line as shown in figure 16, the eyes should be on:

a. (A), the dot toward which the pencil is moving.

b. (B), the pencil point.

c. (C), the line which has been drawn.

d. it makes no difference.

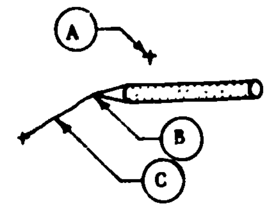


Figure 16

33. The equipment and material needed for sketching are:

a. pencil and paper.

b. pencil, eraser and paper.

c. pencil, eraser, straightedge and paper.

d. pencil, eraser, scale and paper.

34. The paper shown in figure 17 would be most helpful in:

a. multi-view sketching.

b. oblique sketching.

c. isometric sketching.

d. perspective sketching.

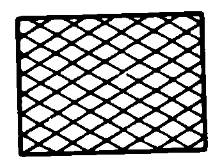


Figure 17

35. The linework in the sketch in figure 18:

a. should be darker.

b. should show more contrast in weight.

c. should be straighter.

d. is acceptable.

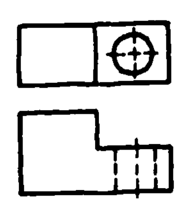


Figure 18

36. Use of the material shown in figure 19 will improve multi-view sketching by:

a. improving the accuracy of distances estimated.

b. improving the accuracy of projection from view to view.

c. increasing speed in sketching.

d. all of the above.

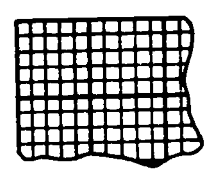


Figure 19

37. A good freehand object line should look like:

a. ———— c. ————

b. ———— d. none of these.

38. A sketch made according to the axes shown in figure 20 would be:

a. an oblique sketch.

b. an isometric sketch.

c. a perspective sketch.

d. none of these.

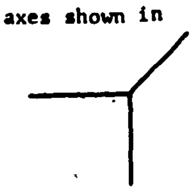
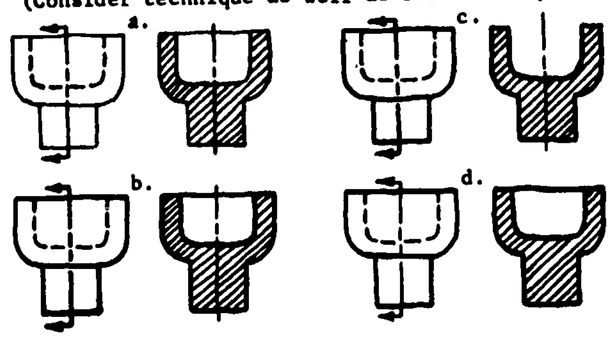


Figure 20

39. The best sketch of the object shown below is: (Consider technique as well as correctness)



40. The type of construction shown in figure 21 is called:

a. box construction.

b. outline construction.

c. preliminary construction.

d. none of these.

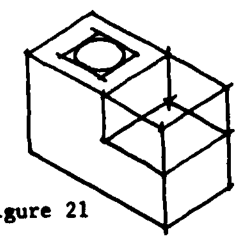


Figure 21

41. The lines shown in figure 22 are often drawn to improve accuracy when sketching:

a. a circle.

b. a hexagon.

c. a square.

d. none of these.

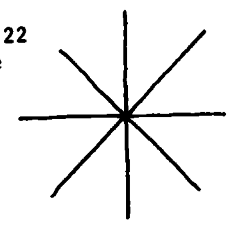
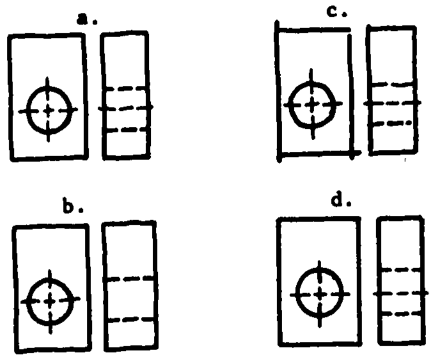


Figure 22

42. The best sketch of the object shown below is (Consider technique as well as correctness)



43. A good freehand construction line should look like:

a.

b.

c.

d. none of these.

Screw Threads and Fasteners

44. Distance 2 shown in figure 23 is the:

a. thread angle.

b. thread depth.

c. pitch.

d. slant.

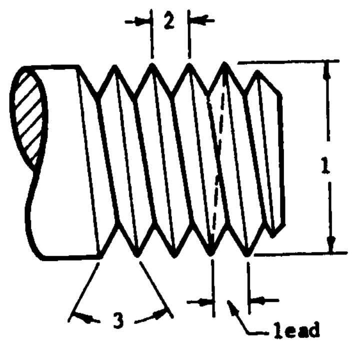


Figure 23

45. Angle 3 shown in figure 23 is:

a. 45°.

b. 60°.

c. 70°.

d. 75°.

46. Distance 1 shown in figure 23 is the:

a. pitch diameter.

b. minor diameter.

c. external diameter.

d. major diameter.

47. The thread shown in figure 23 is a:

a. single thread.

b. double thread.

c. triple thread.

d. it is impossible to tell.

48. The thread representation shown in figure 23 is:

a. a schematic representation.

b. a detailed representation.

c. a pictorial representation.

d. a simplified representation.

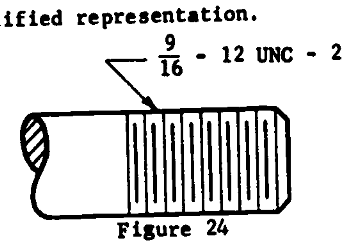


Figure 24

49. The 12 in the note in figure 24 indicates:

a. number of threads per inch.

b. the length of the bolt.

c. the length of the thread.

d. the number of bolts required.

50. The thread representation shown in figure 24 is:

a. an alternate representation.

b. an incorrect representation.

c. a schematic representation.

d. a simplified representation.

51. The UNC in the note in figure 24 indicates the:

a. thread number.

b. thread series.

c. thread class.

d. type of representation.

Pictorial Drawing

52. In an isometric drawing, angle A shown in figure 25 is:
   a. 100°. c. 120°.
   b. 115°. d. none of these.

53. In an isometric drawing, angle B shown in figure 25 is:
   a. 30°. c. 20°.
   b. 25°. d. none of these.

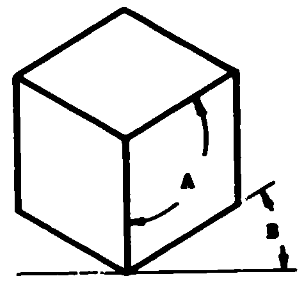
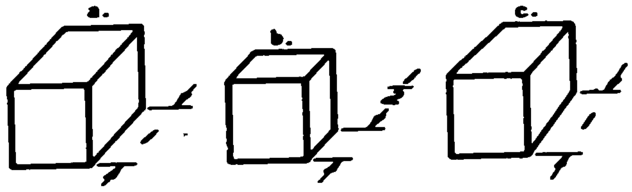


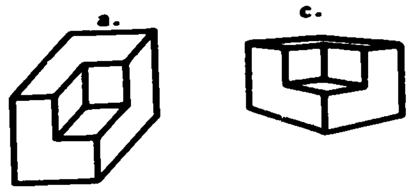
Figure 25

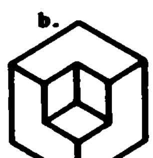
54. A cabinet drawing of a cube should look like:



d. none of these

55. An isometric drawing of the object shown in figure 26 should look like:





d. None of these.

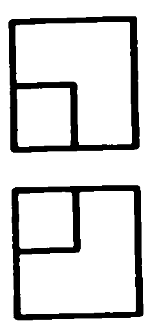


Figure 26

56. To construct the irregular curve shown in figure 27 in an isometric drawing you must:
   a. place several points along the curve, locate these points in the isometric drawing, and connect them with an irregular curve.
   b. find center for several arcs which compose the curve, locate these centers in the isometric drawing, and draw the line with a compass.
   c. find the centers for several arcs which compose the curve, locate these in the isometric drawing and construct the line using several approximate four-center ellipses.
   d. none of these are correct.

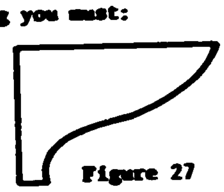


Figure 27

57. When measuring in an isometric drawing, the proper scale to use is:
   a. an isometric scale. c. an ordinary scale.
   b. a metric scale. d. any of these.

58. To draw line 1,2 shown in figure 28 in an isometric drawing you must:
   a. locate point 2 and draw from 2 to 1 with a 60° angle.
   b. locate point 1 and draw from 1 to 2 with a 60° angle.
   c. locate points 1 and 2 and connect them with a straightedge.
   d. none of these are correct.

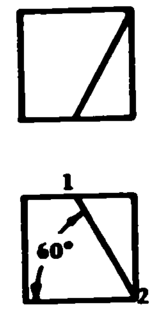


Figure 28

59. Line 1,2 in figure 28 is called:
   a. an isometric line. c. an angle line.
   b. an irregular line. d. a nonisometric line.

60. The type of projection shown in figure 29 is:
   a. isometric. c. perspective.
   b. orthographic. d. oblique.

61. If dimension A in figure 29 is drawn half-size, the drawing is called:
   a. cabinet. c. cavalier.
   b. half-size. d. isometric.

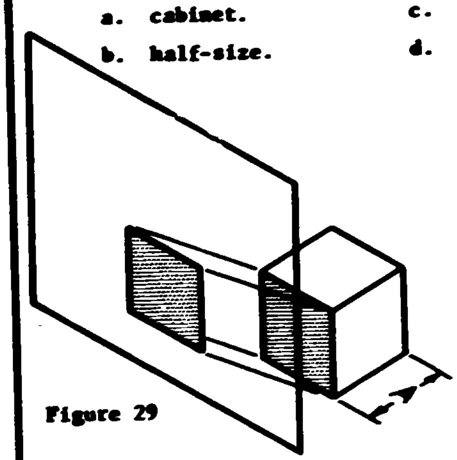


Figure 29

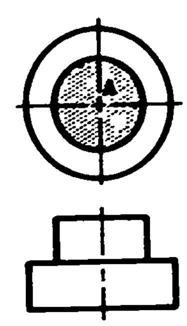


Figure 30

62. To make an effective oblique projection of the object shown in figure 30, surface A should be:
   a. parallel to the plane of projection.
   b. perpendicular to the plane of projection.
   c. at a 45° angle to the plane of projection.
   d. at a 30° angle to the plane of projection.

63. A nonisometric line shown in figure 32 is:
   a. DE.
   b. BC.
   c. AE.
   d. CD.

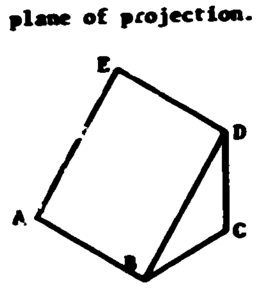


Figure 31

64. A cavalier drawing of the object shown in figure 32 should look like:

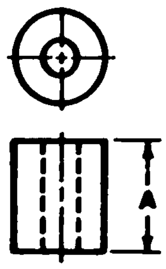
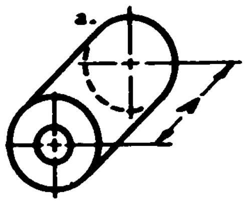
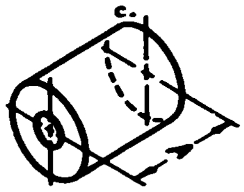


Figure 32

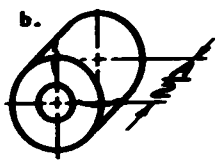
a.



c.



b.



d. None of these.

65. The best method of drawing the arc shown in figure 33 in an isometric drawing is to:

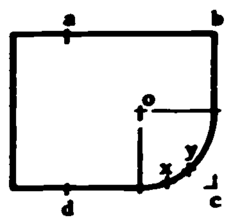


Figure 33

a. locate the center and draw the arc with a compass.

b. locate points on the arc, such as x and y, and connect them with an irregular curve.

c. block in square abcd and use a portion of an approximate four-center ellipse.

d. none of these.

66. The type of axonometric projection shown in figure 34 is:

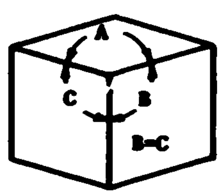


Figure 34

a. isometric.

b. dimetric.

c. trimetric.

d. none of these.

END OF PART 1

Go On immediately if you are being tested in one double period testing session.

Stop if you are being tested in two single period testing sessions. Place your answer sheet inside your examination booklet with your name sticking out. This will facilitate the re-issuing of materials at the beginning of session number two.

Orthographic Projection

67. Line (D) in figure 35 is:
   a. a phantom line.
   b. a dotted line.
   c. a hidden line.
   d. a center line.

68. Line (C) in figure 35 is:
   a. a cutting plane line.
   b. a hidden line.
   c. a middle line.
   d. a center line.

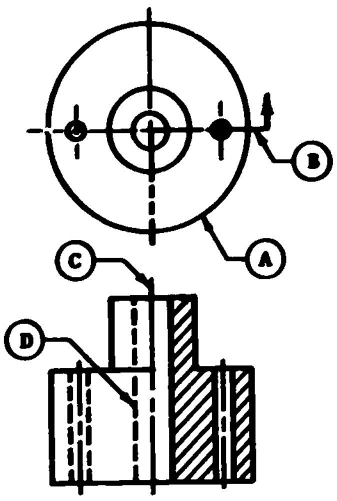
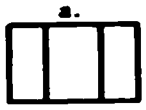
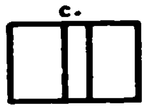
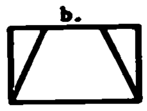


Figure 35

69. Line (A) in figure 35 is:
   a. an outline.
   b. a solid line.
   c. an object line.
   d. an exterior line.

70. Line (B) in figure 35 is:
   a. a center line.
   b. a section line.
   c. a cutting plane line.
   d. an object line.

71. The top view of the object shown in figure 36 should look like:

a.

c.

b.

d. none of these

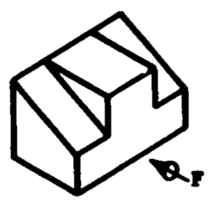
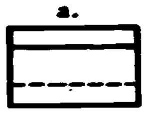
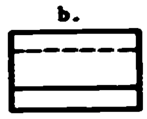
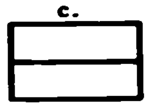


Figure 36

72. The front view of the object shown in figure 37 should look like:

a.

b.

c.

d. none of these

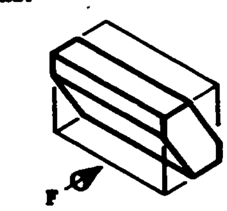
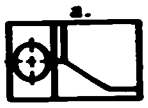
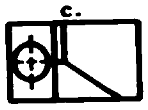
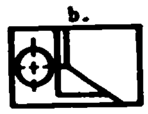


Figure 37

73. The top view of the object shown in figure 38 should look like:

a.

c.

b.

d. none of these

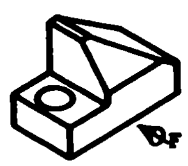


Figure 38

74. Plane DCH shown in figure 39 will project true shape in:
   a. the front view.
   b. the top view.
   c. the right side view.
   d. an auxiliary view.

75. Plane CGFH shown in figure 39 will project true shape in:
   a. the front view.
   b. the right side view.
   c. the top view.
   d. an auxiliary view.

76. Line AD shown in figure 39 will project true length in:
   a. the top view.
   b. the front view.
   c. the right side view.
   d. an auxiliary view.

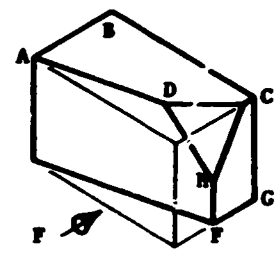


Figure 39

77. To be complete, the object shown in figure 40 should have:
   a. an object line from e to f.
   b. an object line from a to b.
   c. an object line from c to d.
   d. none of these.

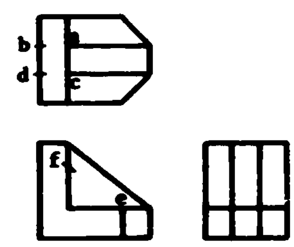
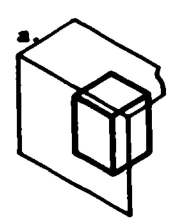
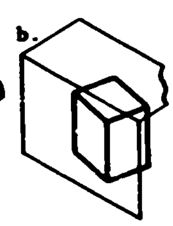
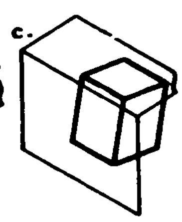


Figure 40

78. To completely describe an object with orthographic multi-view projection, the best relationship of the object to the principal planes of projection is:

a.

b.

c.

d. none of these

79. Plane A in figure 41 is:
   a. a profile plane.
   b. a frontal plane.
   c. an inclined plane.
   d. a horizontal plane.

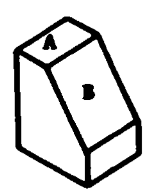
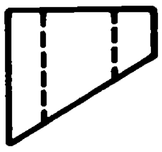


Figure 41

80. Plane B in figure 41 is:
   a. a frontal plane.
   b. a profile plane.
   c. an inclined plane.
   d. a slanted plane.



81. The best right side view of the object shown in figure 42 is: (Consider technique as well as correctness.)

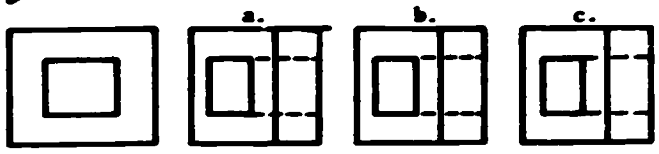
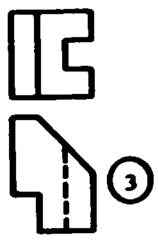
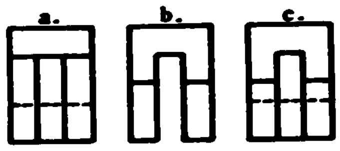


Figure 42

d. all are equally as good.

82. View (3) of the object shown in figure 43 should look like:

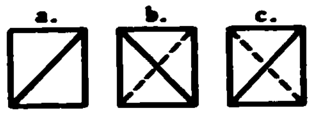




d. none of these

Figure 43

83. The right side view of the object shown in figure 44 should look like:



d. None of these

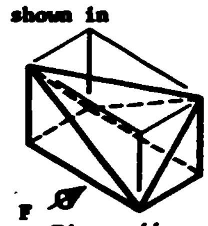


Figure 44

84. View (3) of the object shown in figure 45 should look like:

d. Any of these.

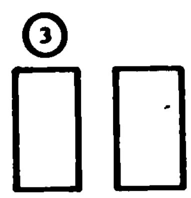


Figure 45

85. To be complete, the object shown in figure 46 should have:

a. an object line from a to b.

b. an object line from c to d.

c. a hidden line from e to f.

d. an object line from e to f.

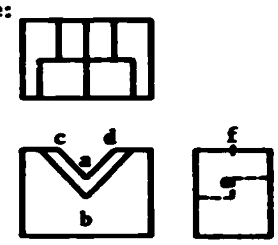


Figure 46

86. To be complete, the object shown in figure 47 should have:

a. an object line from b to d.

b. a hidden line from b to d.

c. an object line from a to c.

d. a hidden line from a to c.

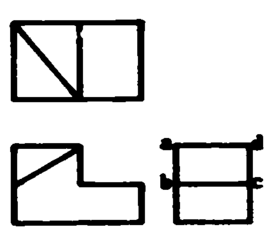


Figure 47

87. The best right side view of the object shown in figure 48 is: (Consider technique as well as correctness.)

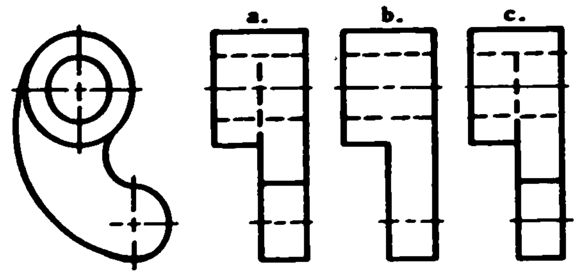


Figure 48

d. all are equally as good.

88. To be complete, the object shown in figure 49 should have:

a. an object line from e to f.

b. a hidden line from b to d.

c. an object line from a to c.

d. an object line from b to d.

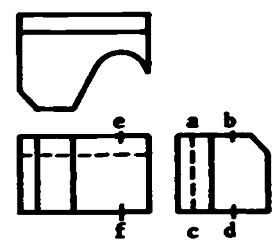


Figure 49

89. In American standard projection, the view of an object that projects onto plane B shown in figure 50 is:

a. the top view.

b. the side view.

c. the front view.

d. an auxiliary view.

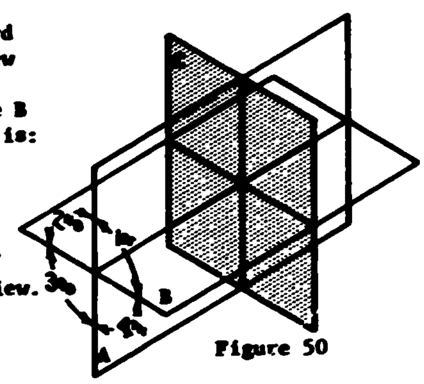
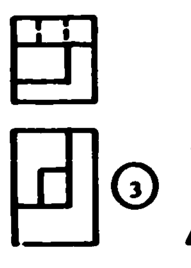
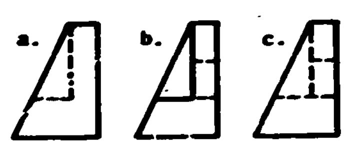


Figure 50

90. View (3) of the object shown in figure 51 should look like:





d. none of these

Figure 51

91. In orthographic projection, the projectors are:

a. perpendicular to the plane of projection.

b. parallel to the plane of projection.

c. at a 45° angle to the plane of projection.

d. at a 30° angle to the plane of projection.

92. In American standard projection, there can be as many as:

a. six principal views.

b. four principal views.

c. three principal views.

d. any number of principal views.

93. The views necessary to completely describe the object shown in figure 53 are:

a. 1, 3 and 5.

b. 1, 3 and 6.

c. 1, 6 and 7.

d. 1, 4 and 7.

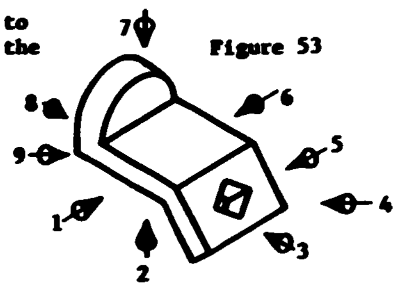


Figure 53

94. The views that would best describe the object shown in figure 54 are:

a. 1, 3 and 6.

b. 1, 4 and 6.

c. 3, 6 and 7.

d. 1 and 7.

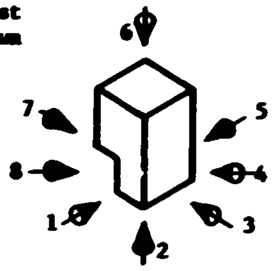


Figure 54

95. The views necessary to completely describe the object shown in figure 55 are:

a. 1, 3 and 6.

b. 1, 6 and 7.

c. 1 and 4.

d. 1 and 3.

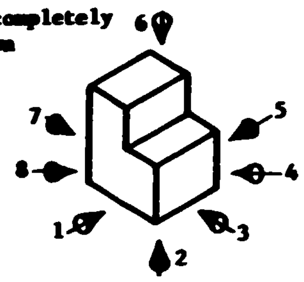


Figure 55

96. View ③ of the object shown in figure 56 should look like:

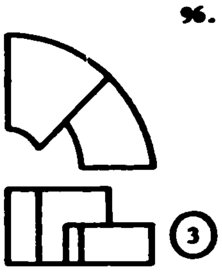
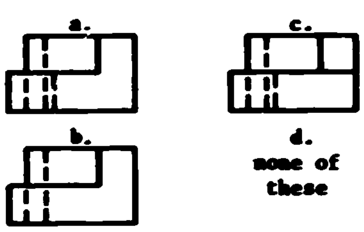


Figure 56



Dimensioning

97. Line ① in figure 57 is:

a. an extension line.

b. a dimension line.

c. a continuation line.

d. an object line.

98. The system of writing dimensions shown in figure 57 is the:

a. only system used.

b. the aligned system.

c. bottom system.

d. unidirectional system.

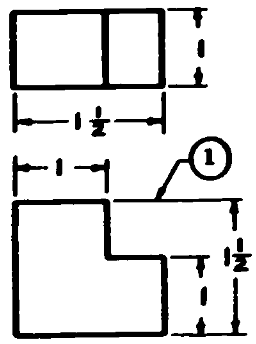


Figure 57

99. The dimensions necessary to completely describe the size of the object in figure 58 are:

a. B, C, D, F, G and I.

b. A, B, C, E, F and J.

c. A, B, D, E, G, H and J.

d. all the dimensions are necessary.

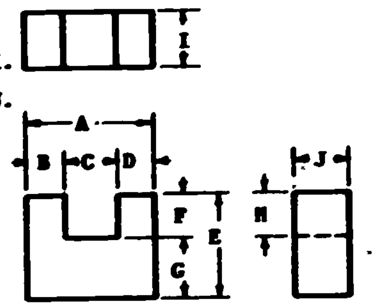


Figure 58

100. If all the dimensions shown in figure 58 are included, which of the fundamental rules of dimensioning is broken?

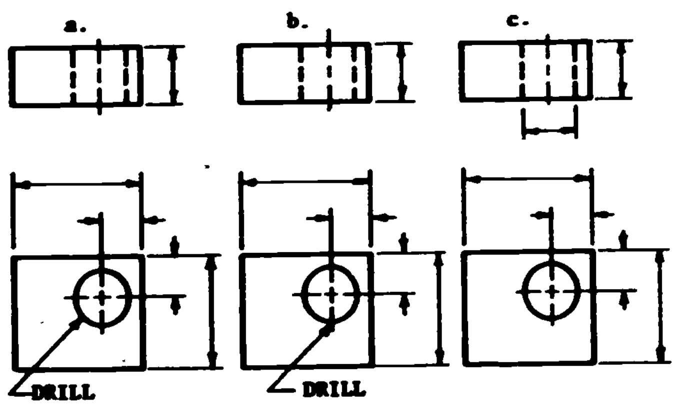
a. Show each dimension only once.

b. Show dimensions between points, lines or surfaces which have a necessary and specific relationship to each other.

c. Where possible, dimension each feature in the view where it appears in profile, and where its true shape appears.

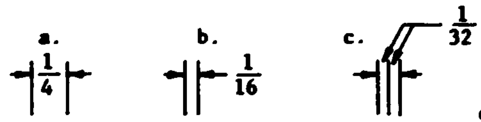
d. No fundamental rule is broken.

101. The best example of dimensioning the object is:



d. All are equally as good.

102. If space is limited, the correct way to indicate dimensions is:



d. all are correct

103. The location dimensions shown in figure 59 are:

a. A, C and B.

b. A and C.

c. B and F.

d. All dimensions are location dimensions.

104. The size dimensions shown in figure 59 are:

a. C, D, E and F.

b. D, E, and F.

c. B, D, E, F and G.

d. All dimensions are size dimensions.

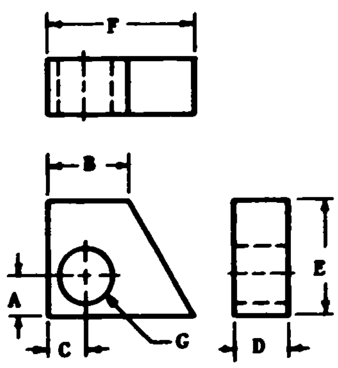
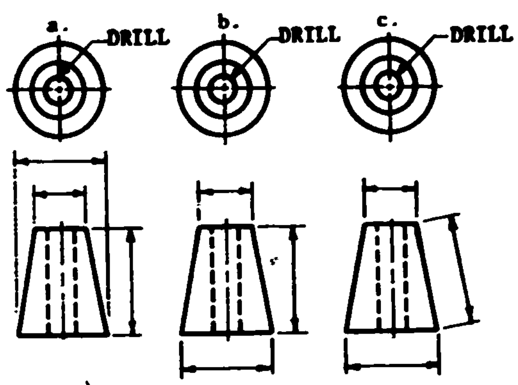


Figure 59

105. The best example of dimensioning the object below is:



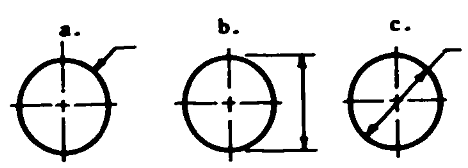
d. all are equally as good.

106. If dimensions are read from the bottom or right side of the sheet, it is called the:

a. right angle system. c. aligned system.

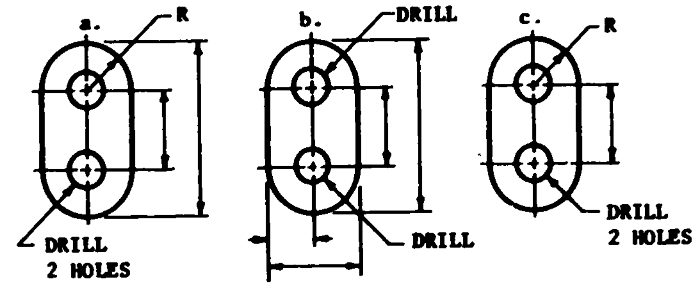
b. coordinate system. d. unidirectional sys' ¬.

107. The way to dimension a hole is:



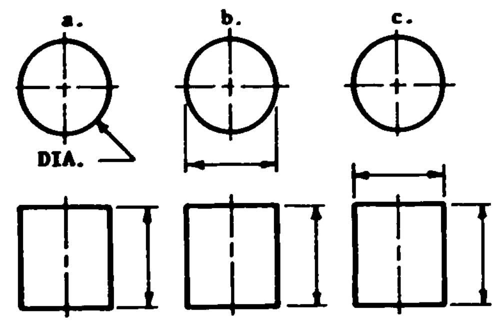
d. all are correct

108. The best example of dimensioning the object below is:



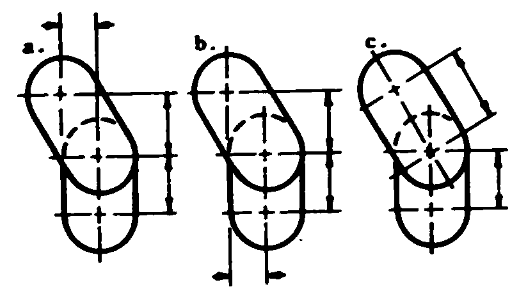
d. all are equally as good.

109. The best example of dimensioning the object below is:



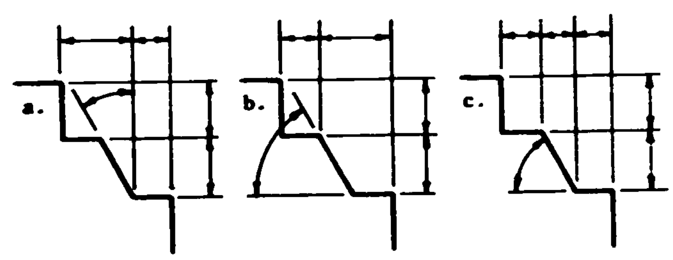
d. all are equally as good.

110. The best example of placing location dimensions on the object below is:



d. all are equally as good.

111. The best example of dimensioning the feature below is:



d. all are equally as good.

Sections and Conventions

112. The illustration in figure 60 represents a break in a long piece of:
   a. round solid material.
   b. round tubular material.
   c. elliptical tubular material.
   d. elliptical solid material.

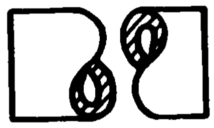


Figure 60

113. The sectional view produced according to plane B in figure 61 would be:
   a. an alternate section.
   b. a broken-out section.
   c. an offset section.
   d. a double section.

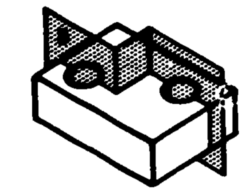


Figure 61

114. The sectional view illustrated in figure 62 is:
   a. a revolved section.
   b. a removed section.
   c. a turned section.
   c. a center section.

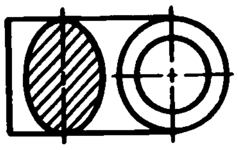


Figure 62

115. The sectional view produced according to plane A in figure 63 would be:
   a. a full section.
   b. a half section.
   c. an auxiliary section.
   d. an alternate section.

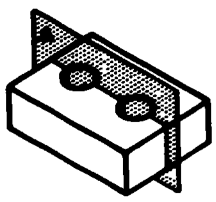
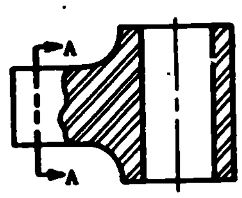


Figure 63

116. The sectional view illustrated in figure 64 is:
   a. a broken-out section.
   b. a full section.
   c. a partial section.
   d. an auxiliary section.



117. Section AA shown in figure 64 is:
   a. a cross section.
   b. a revolved section.
   c. a broken-out section.
   d. a removed section.

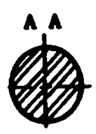
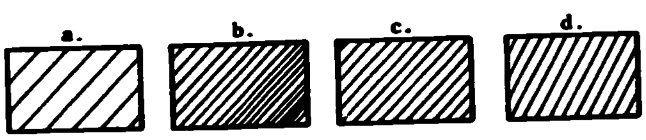


Figure 64

118. The best illustration of section lining below is:



119. The sectional view illustrated in figure 65 is:
   a. a full section.
   b. a one-fourth section.
   c. a half section.
   d. a broken-out section.

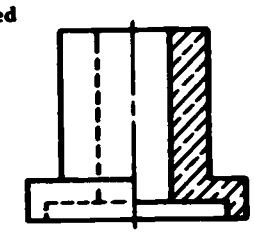
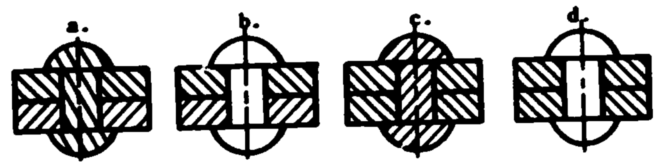


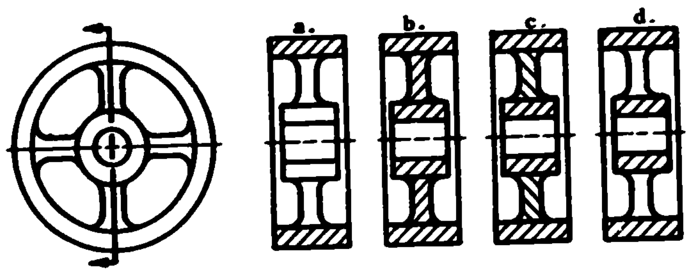
Figure 65

120. The object in figure 65 is made of:
   a. bronze.
   b. aluminum.
   c. porcelain.
   d. lead.

121. The best representation of a sectional view of two pieces of material held together by a rivet is:



122. The best sectional view of the object below is:



123. The sectional view illustrated in figure 66 is:
   a. an offset section.
   b. an inset section.
   c. a full section.
   d. an assembly section.

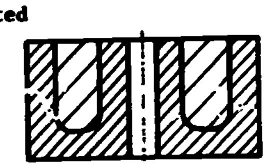
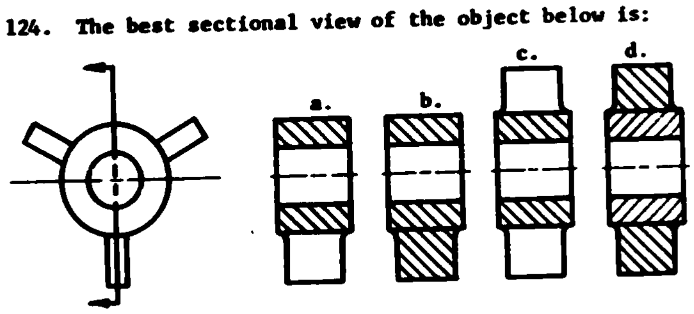


Figure 66

124. The best sectional view of the object below is:



125. The sectional view illustrated in figure 67 is:
   a. a full section.
   b. an alternate section.
   c. an assembly section.
   d. a half section.

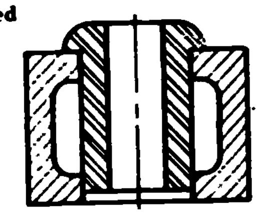


Figure 67

126. The sectional view produced according to plane D in figure 68 would be:

a. a full section.

b. a partial section.

c. a half section.

d. a broken-out section.

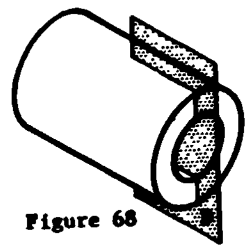


Figure 68

Auxiliaries

127. The plane shown in figure 69 that would project true shape in an auxiliary view is:

a. plane A.

b. plane B.

c. plane C.

d. plane D.

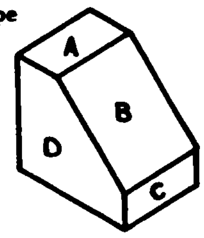


Figure 69

128. The true shape of the inclined plane shown in figure 70 is:

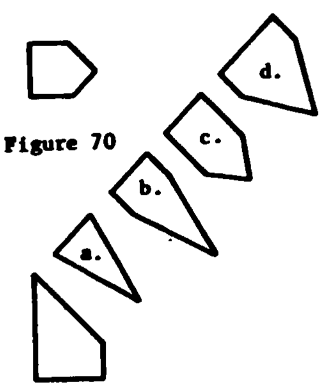


Figure 70

129. The correct direction for the line of sight for an auxiliary in which surface Z shown in figure 71 will app ar true shape is:

a. A.

b. B.

c. C.

d. D.

130. To completely describe the object shown in figure 71, it would be necessary to draw a:

a. top view.

b. complete auxiliary view.

c. partial auxiliary view.

d. top view and a partial auxiliary view.

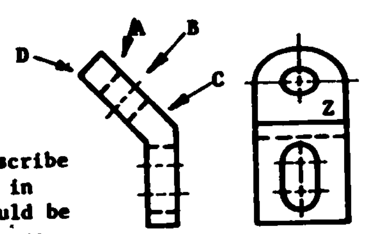


Figure 71

131. Every object has three main dimensions, width, height and depth. Which of these will appear in an auxiliary view taken in the direction of arrow A in figure 71?

a. height and depth.

b. depth only.

c. height and width.

d. height only.

132. The true shape of the inclined plane shown in figure 72 is:

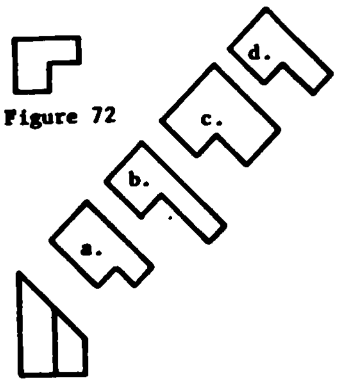


Figure 72

133. The true shape of the inclined plane shown in figure 73 is:

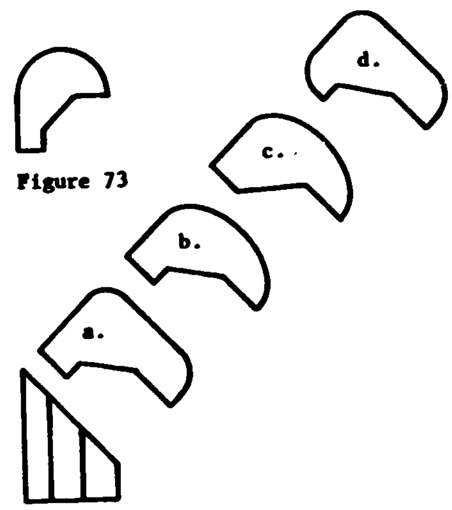


Figure 73

134. The top and front views of line ab are given in figure 74. The correct direction for the line of sight for an auxiliary view in which ab will appear true length is:

a. A.

b. B.

c. C.

d. D.

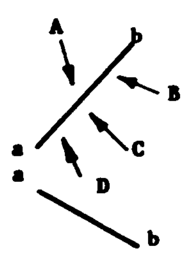


Figure 74

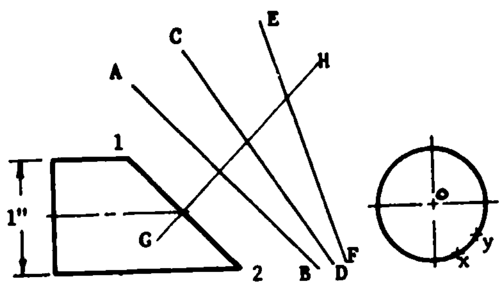


Figure 75

135. To draw inclined plane 1,2 shown in figure 75 true shape, it is necessary to project that plane onto an auxiliary plane of projection that is perpendicular to the frontal plane of projection and parallel to line:

a. AB. c. EF.

b. CD. d. GH.

136. The construction necessary to complete the auxiliary view showing inclined plane 1,2 in figure 75 true shape is:

a. to locate center o in the auxiliary view, draw center lines through center o, and complete the drawing by executing an approximate four-center ellipse.

b. to locate center o in the auxiliary view and draw a circle with a diameter of 1".

c. to mark off points such as x and y on the circumference in the right side view, locate these points in the auxiliary view and connect them with an irregular curve.

c. none of these are correct.

137. Dimension 1 in figure 76 is found by measuring distance:

a. A.

b. B.

c. C.

d. none of these.

138. The auxiliary view shown in figure 76 is:

a. an elevation auxiliary.

b. a top auxiliary.

c. a front auxiliary.

d. a right auxiliary.

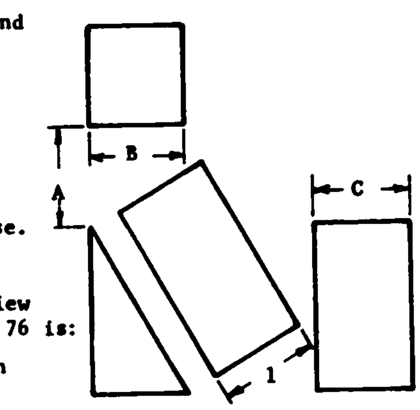
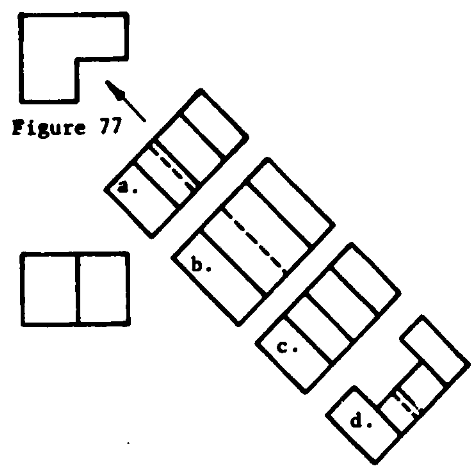


Figure 76

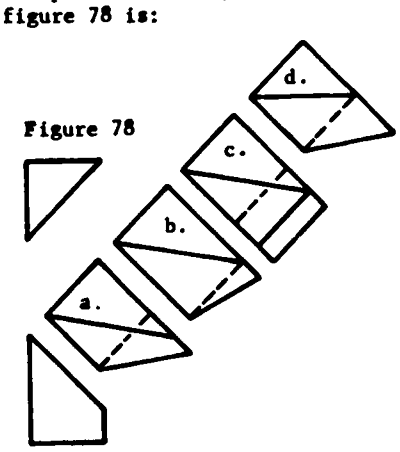
139. The complete auxiliary view drawn according to the line of sight shown in figure 77 is:

Figure 77



140. The complete auxiliary view of the object shown in figure 78 is:

Figure 78



A SCALE TO MEASURE ATTITUDE TOWARD ANY SCHOOL SUBJECT

Form A **Edited by H. H. Remmers**

Date________________

Name (optional)____________________________ Sex (circle one) M F

Age________________________ Grade________________________

Directions: Following is a list of statements about school subjects. Put a plus sign (+) before each statement with which you agree about the subjects listed at the left of the statements. The person in charge will tell you the subject or subjects to write in at the head of the columns to the left of the statements. Your score will not affect your grade in any course.

Subject					
					1. No matter what happens, this subject always comes first.
					2. This subject has an irresistible attraction for me.
					3. This subject is profitable to everybody who takes it.
					4. Any student who takes this subject is bound to be benefited.
					5. This subject is a good subject.
					6. All lessons and all methods used in this subject are clear and definite.
					7. I am willing to spend my time studying this subject
					8. This subject is a good pastime.
					9. I don't believe this subject will do anybody any harm.
					10. I haven't any definite like or dislike for this subject.
					11. This subject will benefit only the brighter students.
					12. My parents never had this subject, so I see no merit in it.
					13. I am not interested in this subject.
					14. This subject reminds me of Shakespeare's play -- "Much Ado About Nothing."
					15. I would not advise anyone to take this subject.
					16. This subject is a waste of time.
					17. I look forward to this subject with horror.

A SCALE TO MEASURE ATTITUDE TOWARD ANY SCHOOL SUBJECT

Form B

Edited by H. H. Remmers

Date________________

Name (optional)______________________________ Sex (circle one) M F

Age____________________ Grade________________________

Directions: Following is a list of statements about school subjects. Put a plus sign (+) before each statement with which you agree about the subjects listed at the left of the statements. The person in charge will tell you the subject or subjects to write at the head of the columns to the left of the statements. Your score will not affect your grade in any course.

Subject

1. I am "crazy" about this subject.
2. I believe this subject is the basic one for all high school courses.
3. This subject fascinates me.
4. This subject will help pupils socially as well as intellectually.
5. This subject is interesting.
6. All methods used in this subject have been thoroughly tested in the classroom by experienced teachers.
7. Every year more students are taking this subject.
8. This subject has its drawbacks, but I like it.
9. This subject might be worthwhile if it were taught right.
10. My likes and dislikes for this subject balance one another.
11. This subject is all right, but I would not take any more of it.
12. No student should be concerned with the way this subject is taught.
13. This subject has numerous limitations and defects.
14. This subject seems to be a necessary evil.
15. All of the material in this subject is very uninteresting.
16. This subject has no place in the modern world.
17. This subject is all bunk.

ATTITUDE SCALE ANSWER SHEET AND STUDENT INFORMATION FORM

Name (Last, First, Middle) ____________ Date ____________ Age ________

Student Number ____________ Sex (M or F) ____________ Section ____________

Semesters of College Completed ____________ Subject ____________

Form

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17

Differential Aptitude Tests
Form L

Space Relations Test

Abstract Reasoning Test

Published by: The Psychological Corporation
304 East 45th Street
New York, N. Y. 10017

These tests are on file in the Vertical File, Education Reading Room, University of Missouri Library, Columbia, Missouri.

APPENDIX B

Graphic Problem Performance Tests,
Forms A and B

Graphic Problem Performance Test
Evaluative Criteria

Informational Achievement Test

Retention Test of Graphic Problem Performance,
Forms A and B

Graphic Problem Performance Retention Test
Evaluative Criteria

UNIVERSITY OF MISSOURI
MECHANICAL ENGINEERING DEPARTMENT
ME 10 DESCRIPTIVE GEOMETRY

NAME______________________________ SECTION____________

STUDENT NUMBER________________________ DESK____________

GRAPHIC PROBLEM PERFORMANCE

EXAMINATION 2

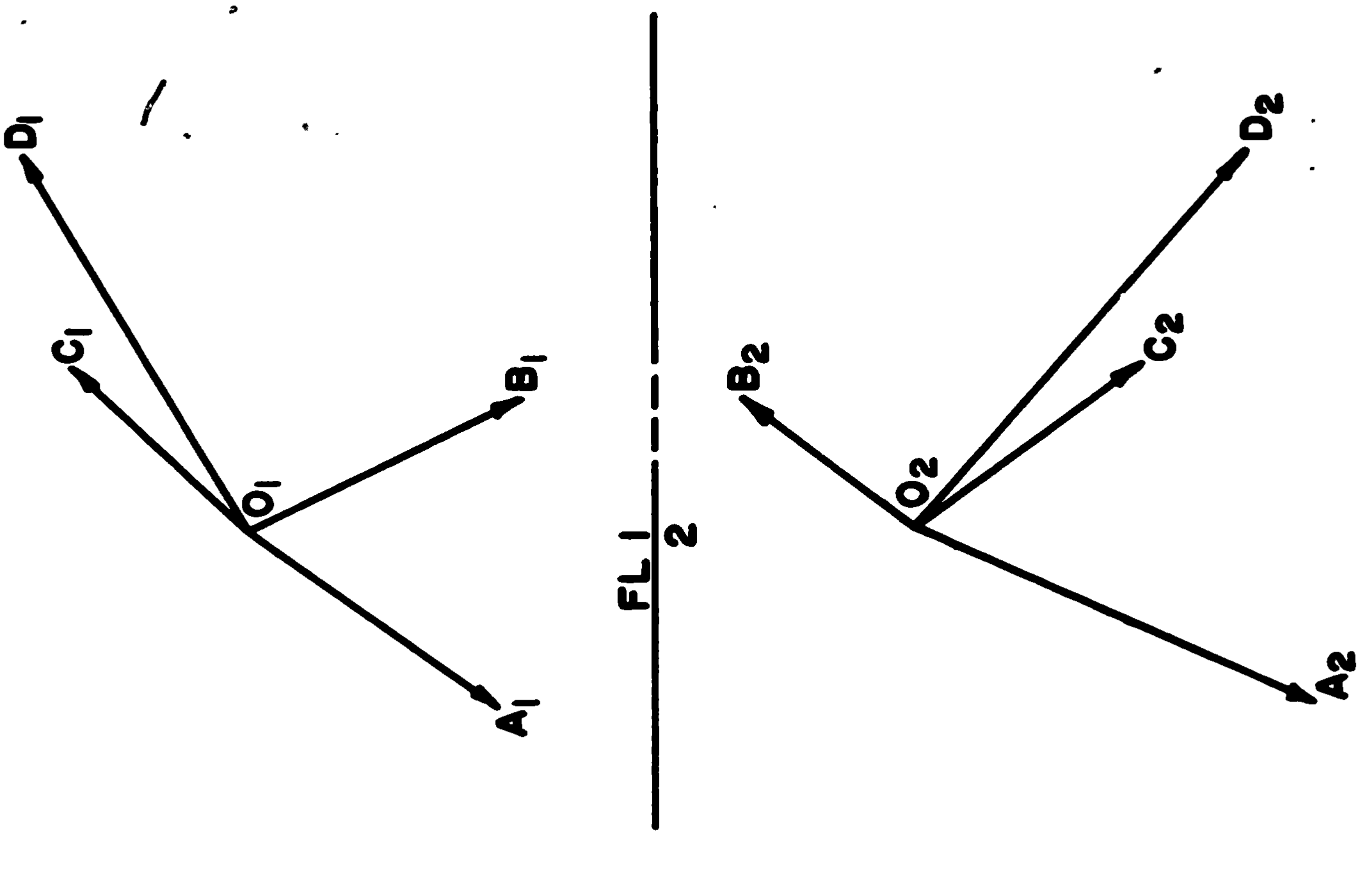
FORM A

General Directions

This is a performance examination designed to measure your ability to solve graphic problems in Descriptive Geometry. It consists of seven (7) problems to be completed according to the instructions given with the problems. Read carefully the instructions for each problem before beginning to work on the problem. You will have two periods (110 minutes) for the completion of the examination.

PROBLEM 1. (15%)

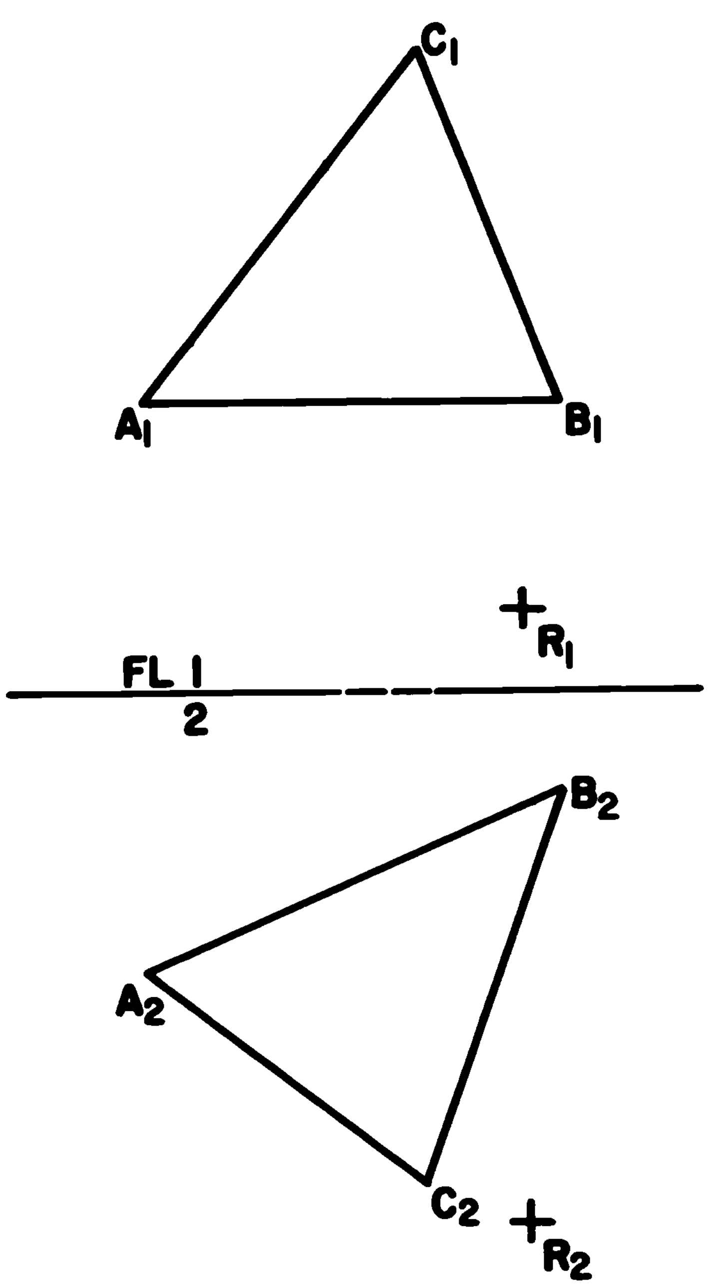
GIVEN: The space diagram shown below drawn to the scale 1" = 30#.
DETERMINE: The magnitude and direction of the resultant force of the system. Use a Vector diagram scale of 1" = 30#.



PROBLEM 2. (10%) Scale: 3" = 1'-0"

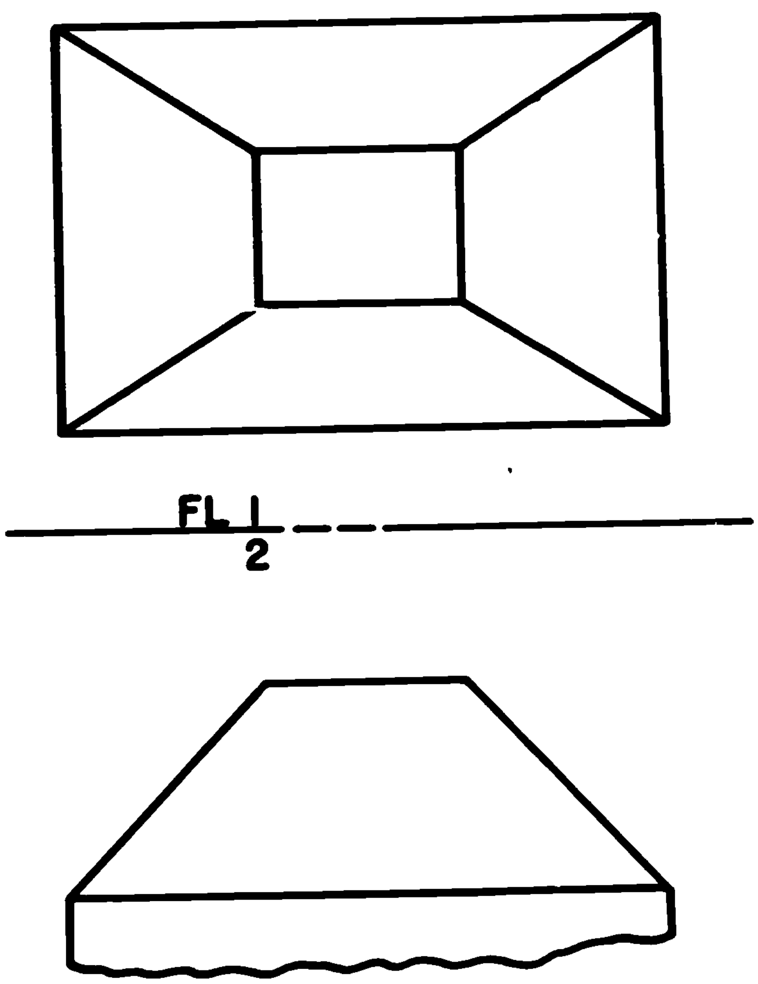
GIVEN: Plane ABC represents an inclined machine surface. Point R is the end of the pulley shaft. The shaft is to be mounted perpendicular to and touching the plane.

DETERMINE: a. The H and F projections of the centerline of the shaft.
b. The length of 1" shaft needed for the installation.



PROBLEM 3. (15%) Scale: 6" = 1'-0"

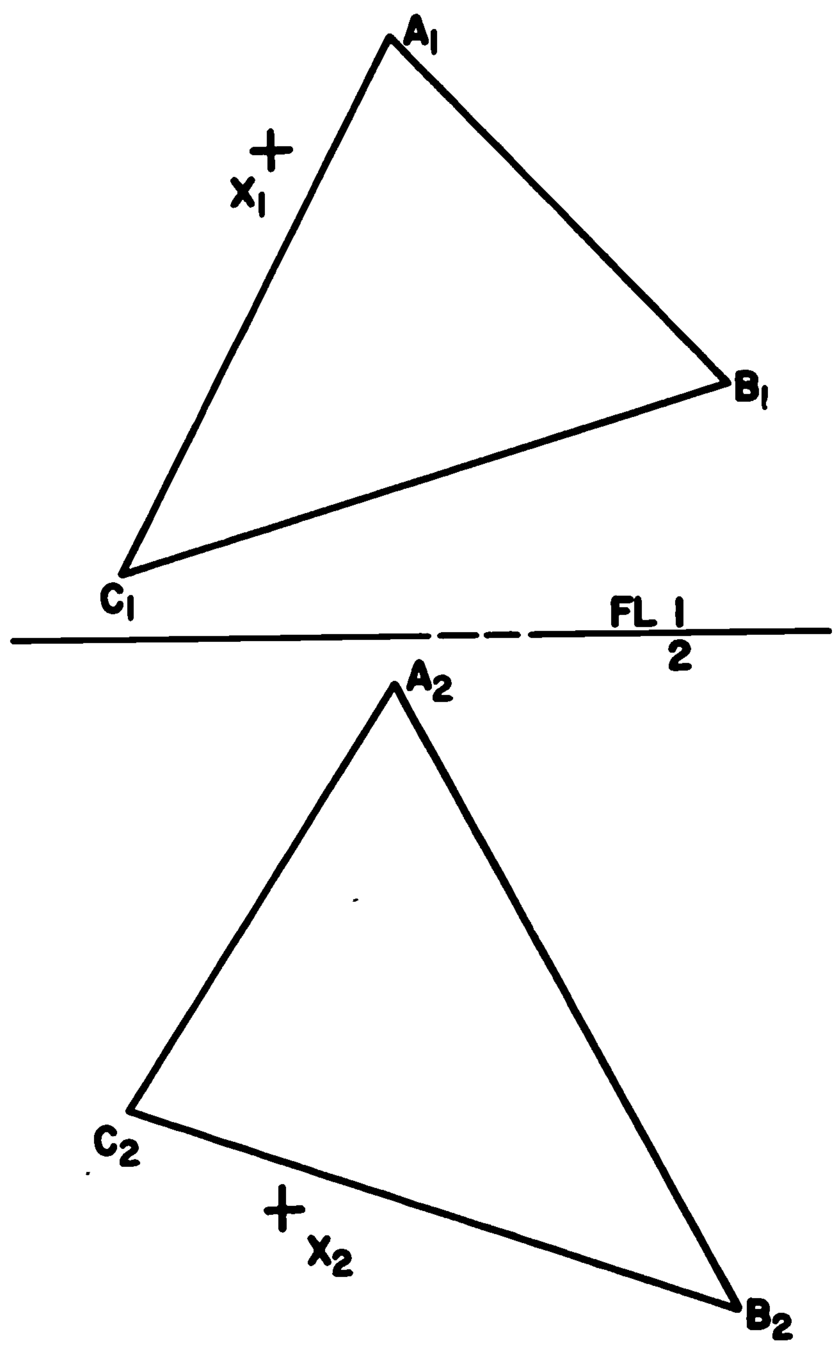
GIVEN: The H and F projections of a concrete bridge pier. A wooden form is needed to retain the concrete while pouring this pier.
DETERMINE: The inside corner angle between the sloping surfaces.



PROBLEM 4. (15%) Scale: 1/2" = 1'-0"

GIVEN: The H and F projections of plane ABC and point X. Line XY has a bearing of S17°E and a positive slope of 65%.

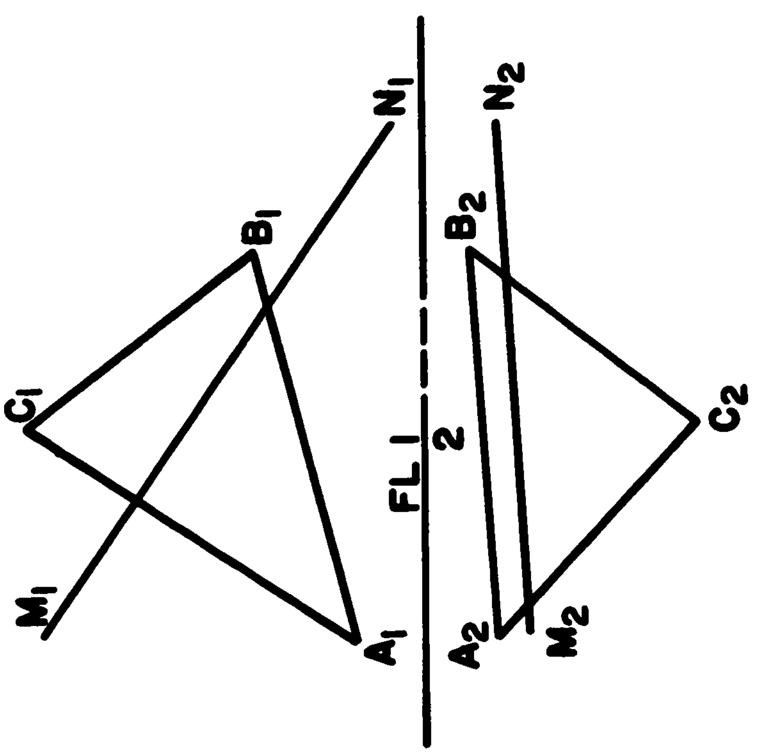
DETERMINE:
a. The T.L. of line XY from point X to the plane.
b. The H and F projections of the line XY. Point Y lies in plane ABC.
c. The slope of the plane in degrees.



PROBLEM 5. (15%) Scale: 12" = 1'-0"

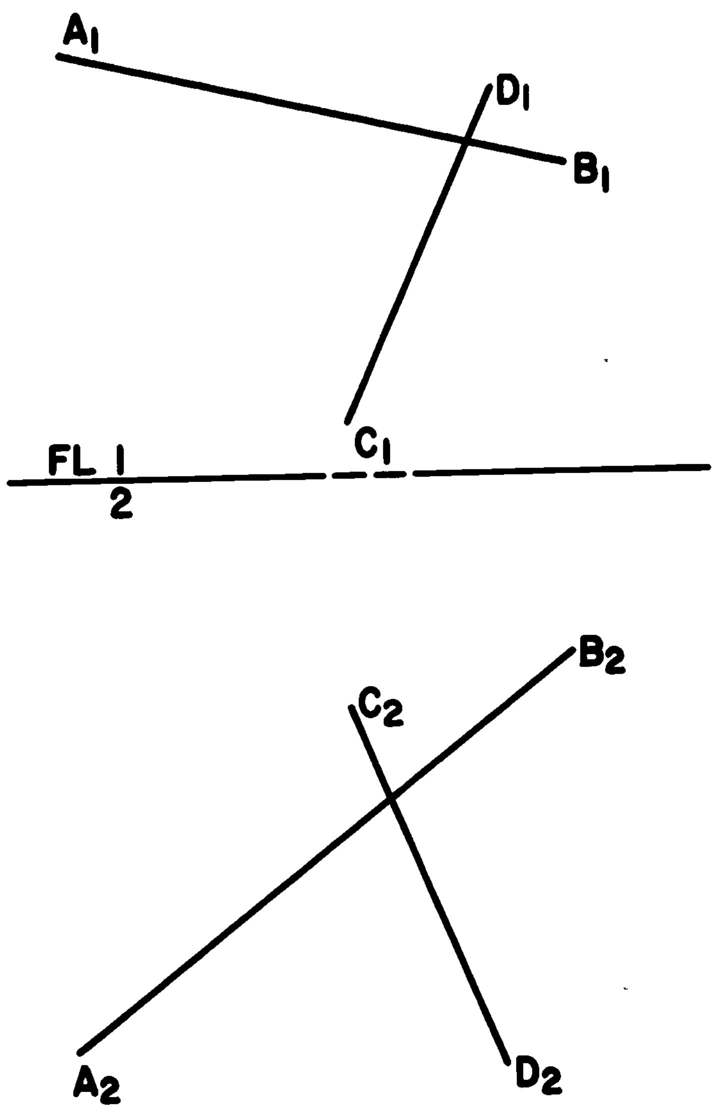
Determine the angle between line MN and plane ABC.

Angle = ___________



PROBLEM 6. (20%) Scale: 1" = 50"

Determine the shortest line having 22° slope joining lines AB and CD. Label this line XY and show the H and F projections of the line. State the bearing, slope and true length of the line.

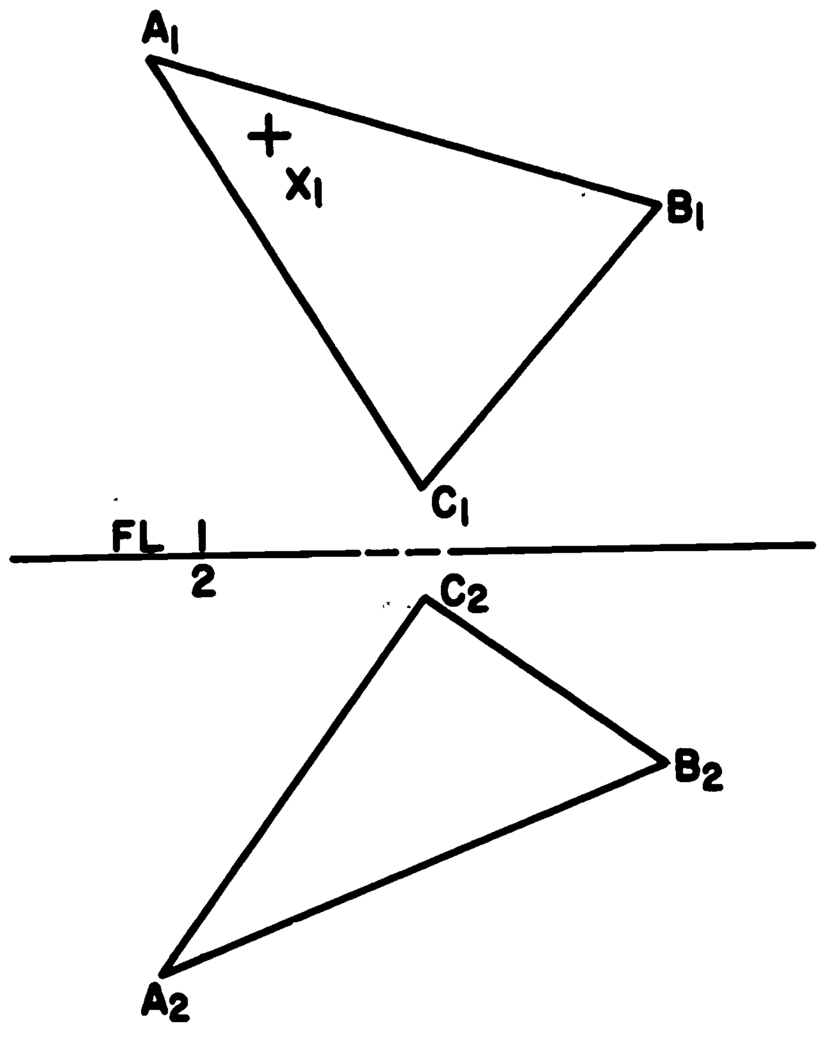


PROBLEM 7. (10%) Scale: 1/2" = 1'-0"

GIVEN: The horizontal reference plane in this drawing represents a level machine top. Point X lies in the plane of this level top. A vertical shaft 1" in diameter is to be installed from point X to the plane ABC.

DETERMINE: a. The centerline length of the 1" shaft.

b. The angle at which the shaft must be cut off to fit against the plane ABC. Measure the angle with the centerline of the shaft.



UNIVERSITY OF MISSOURI
MECHANICAL ENGINEERING DEPARTMENT
ME 10 DESCRIPTIVE GEOMETRY

NAME________________________________ SECTION______________

STUDENT NUMBER________________________ DESK______________

GRAPHIC PROBLEM PERFORMANCE

EXAMINATION 2

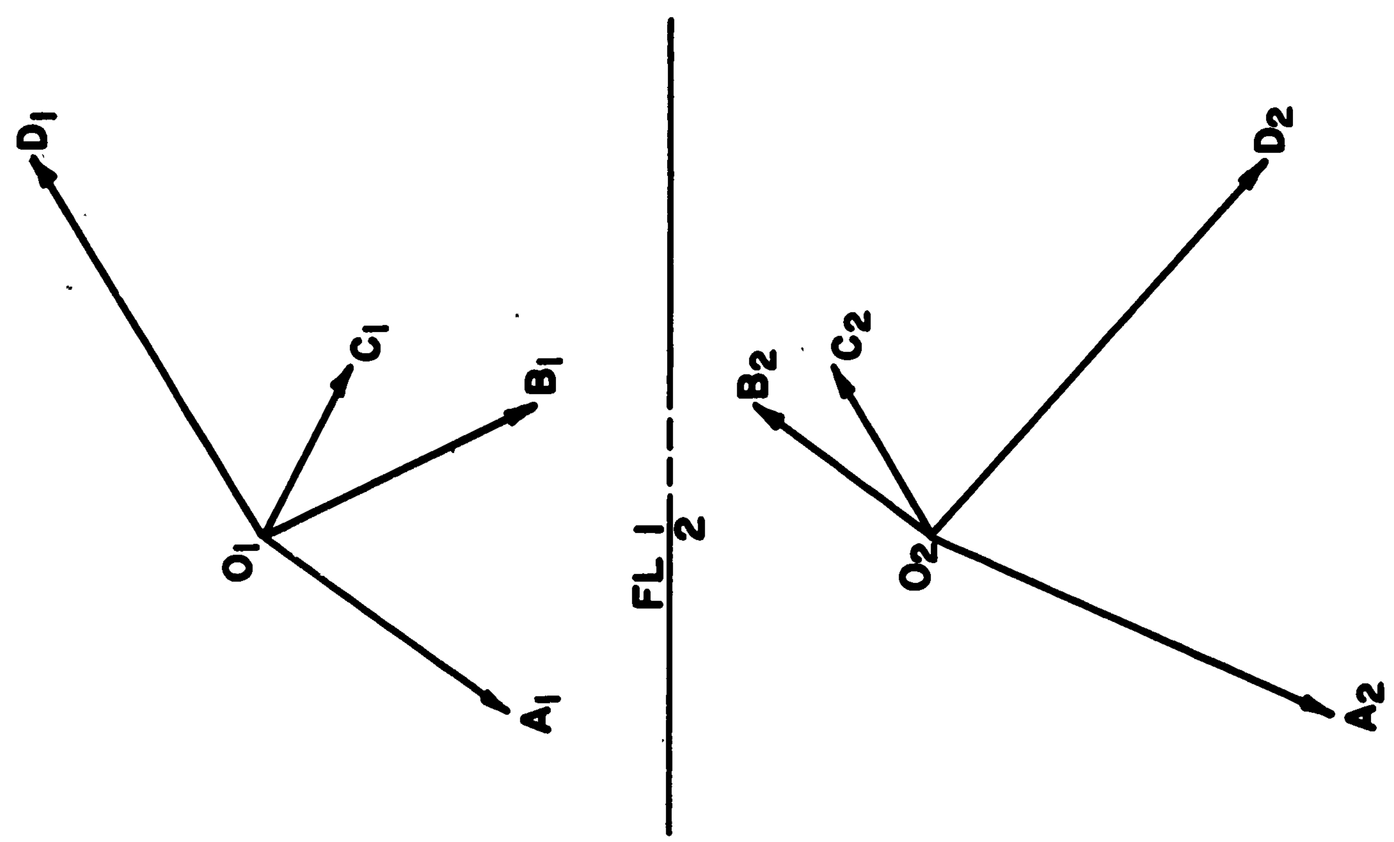
FORM B

General Directions

This is a performance examination designed to measure your ability to solve graphic problems in Descriptive Geometry. It consists of seven (7) problems to be completed according to the instructions given with the problems. Read carefully the instructions for each problem before beginning to work on the problem. You will have two periods (110 minutes) for the completion of the examination.

PROBLEM 1. (15%)

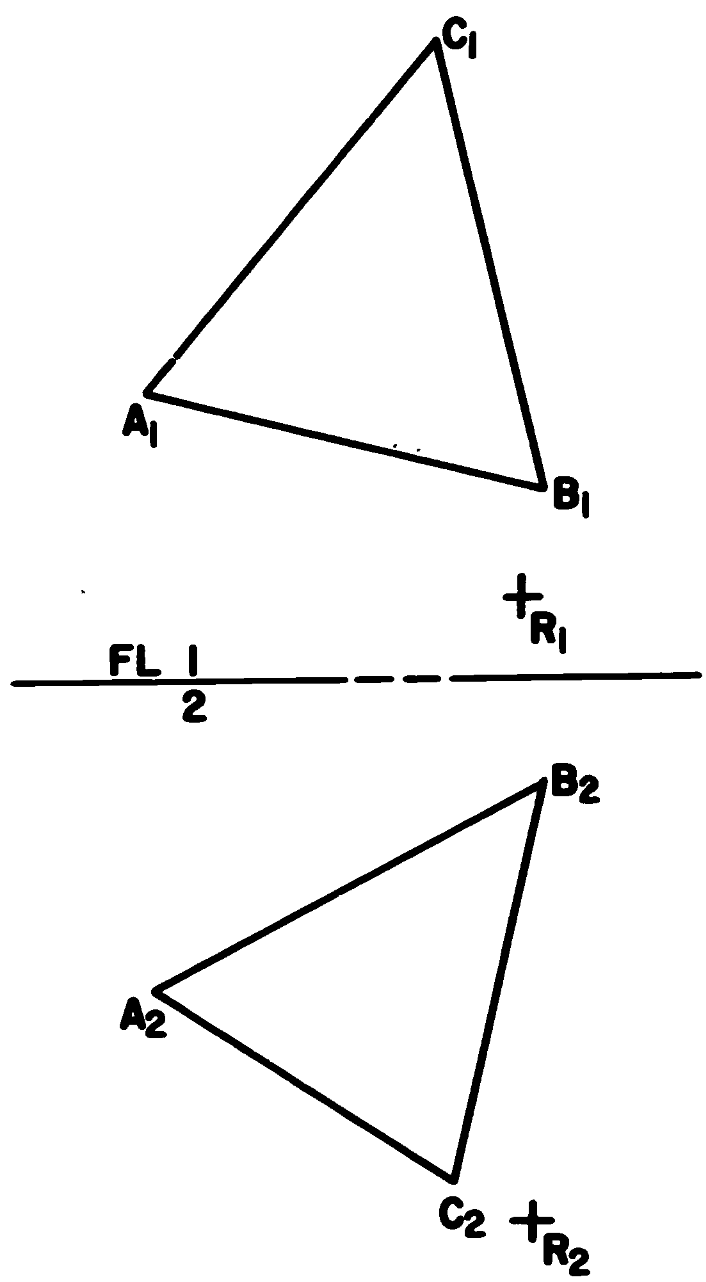
GIVEN: The space diagram shown below, drawn to the scale 1" = 50#.
DETERMINE: The magnitude and direction of the resultant force of the system. Use a vector diagram scale of 1" = 50#.



PROBLEM 2. (10%) Scale: 3" = 1'-0"

GIVEN: Plane ABC represents an inclined machine surface. Point R is the end of the pulley shaft. The shaft is to be mounted perpendicular to and touching the plane.

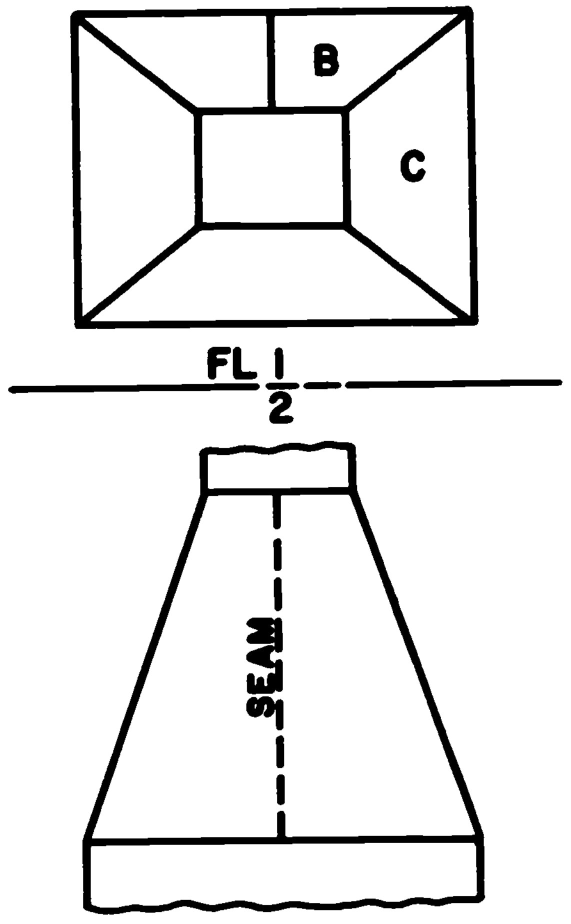
DETERMINE: a. The H and F projections of the centerline of the shaft.
b. The length of 1" shaft needed for this installation.



PROBLEM 3. (15%) Scale: 6" = 1'-0"

GIVEN: The H and F projections of a sheet metal hopper. Find the true size of the bend angle formed by the hopper faces B and C.

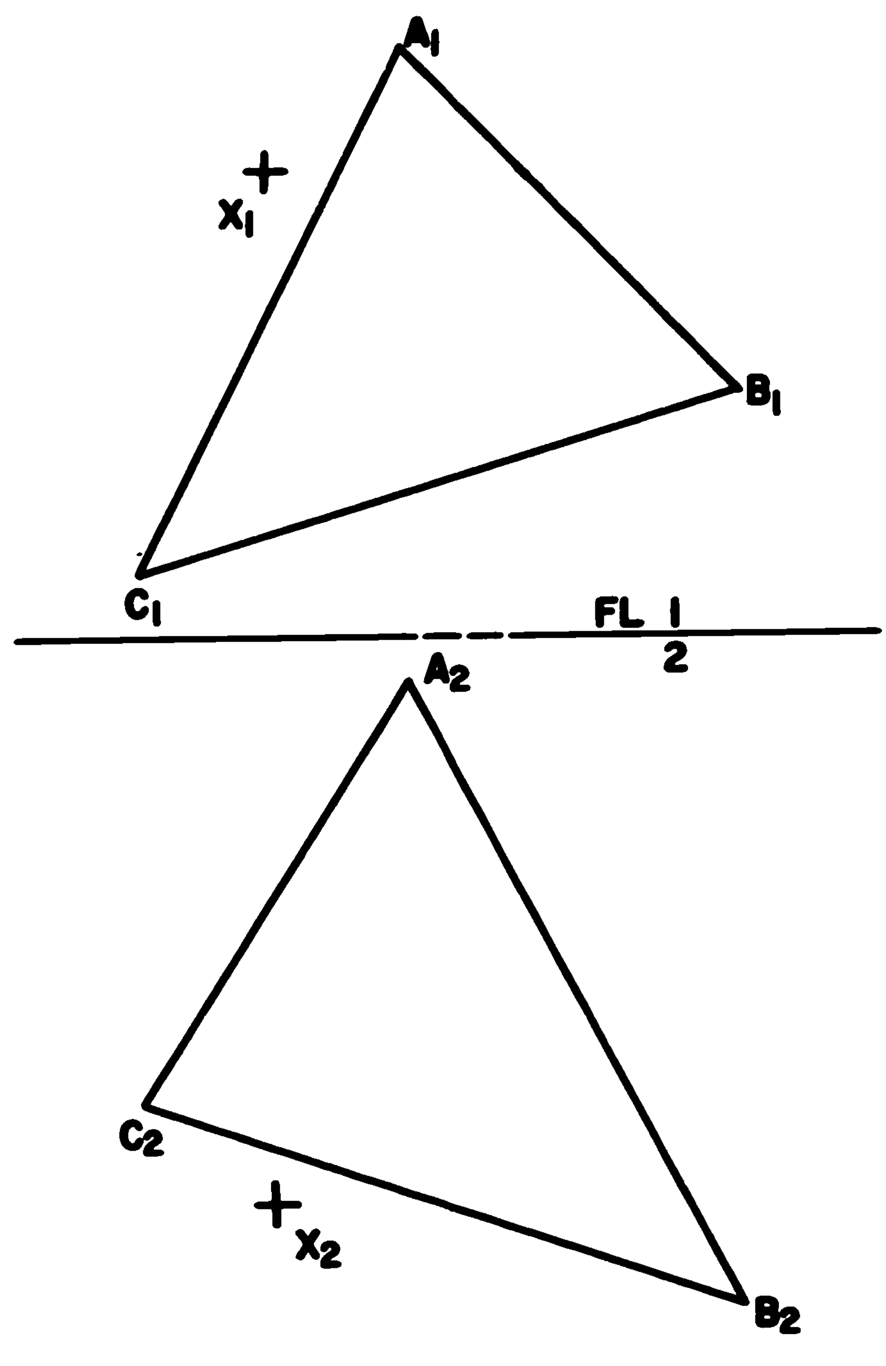
Angle = __________



PROBLEM 4. (15%) Scale: 1/2" = 1'-0"

GIVEN: The H and F projections of plane ABC and point X. Line XY has a bearing of S17°E and a positive slope of 75%.

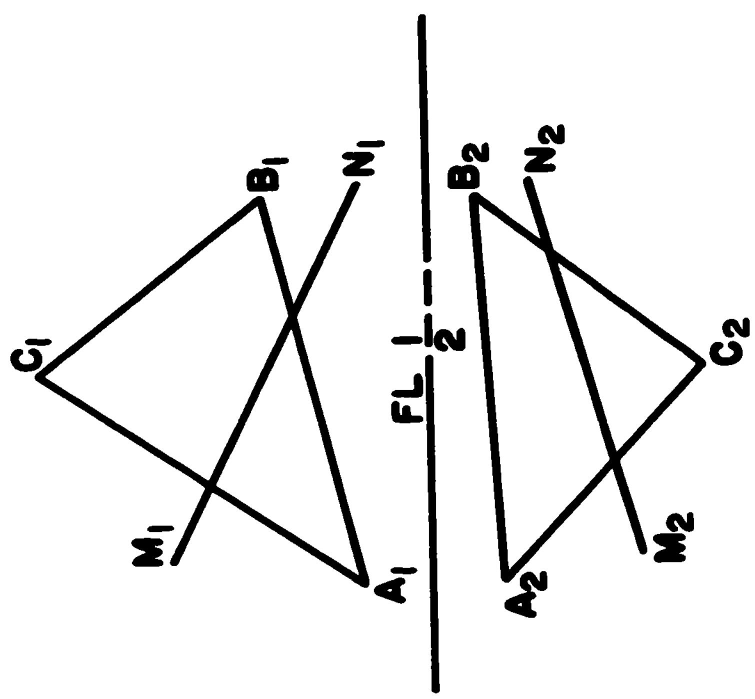
DETERMINE:
a. The T.L. of line XY from point X to the plane.
b. The H and F projections of the line XY. Point Y lies in plane ABC.
c. The slope of the plane in degrees.



PROBLEM 5. (15%) Scale: 12" = 1'-0"

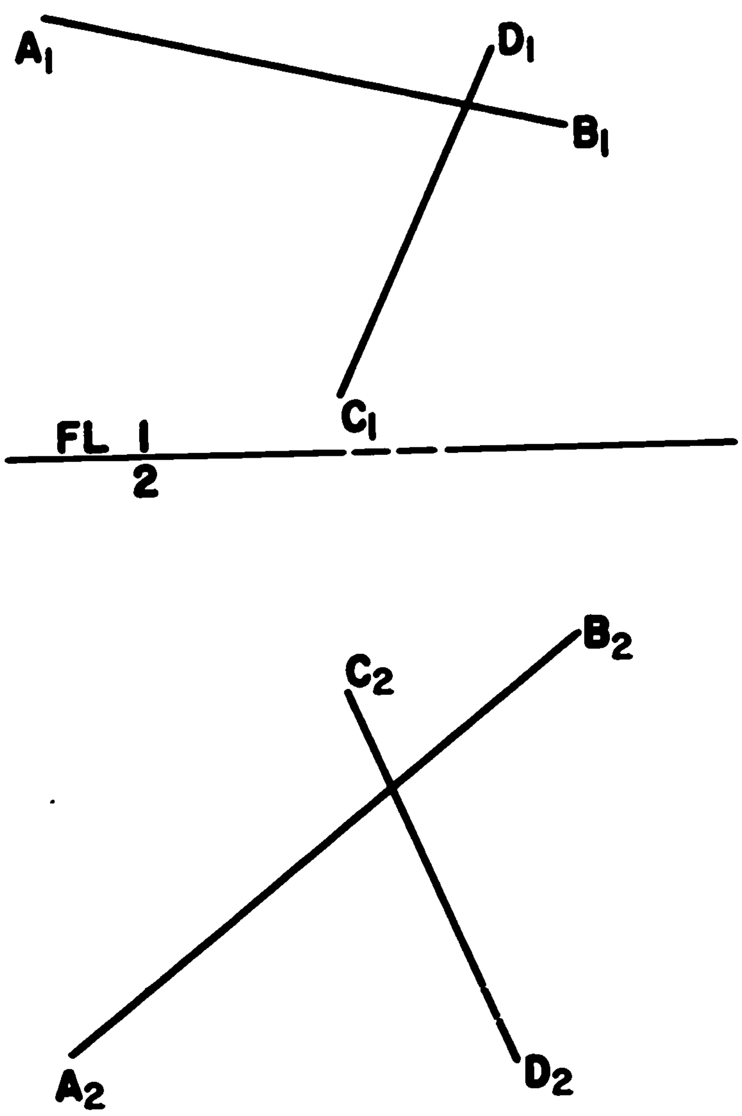
Determine the angle between line MN and plane ABC.

Angle = ________



PROBLEM 6. (20%) Scale: 1" = 40'

Determine the shortest line having 27% slope that will join lines AB and CD. Label this line XY and show the H and F projections of the line. State the bearing and length of the line.

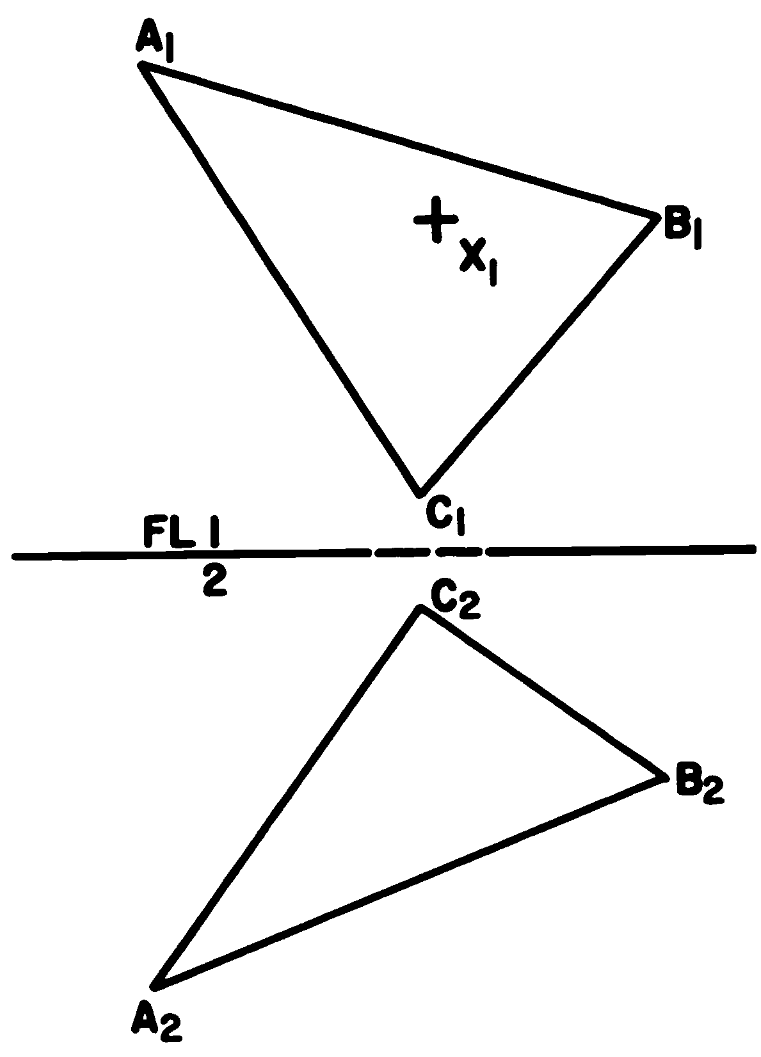


PROBLEM 7. (10%) Scale: 1/2" = 1'-0"

GIVEN: The horizontal reference plane in this drawing represents a level machine top. Point X lies in the plane of this level top. A vertical shaft 1" in diameter is to be installed from point X to the plane ABC.

DETERMINE: a. The centerline length of the 1" shaft.

b. The angle at which the shaft must be cut off to fit against the plane ABC. Measure the angle with the centerline of the shaft.



CRITERIA FOR EVALUATION

Problem #1 (15 points)

Problem Solution -- 12 points

(6) Correct graphic solution and proper projections
(2) Correct magnitude of resultant, within limits
(2) Correct bearing of resultant, within limits
(2) Correct slope of resultant, within limits

General Appearance -- 3 points

(2) All folding lines, vector quantities, and resultant labeled properly
(1) Neatness, erasures, and cleanliness

Problem #2 (10 points)

Problem Solution -- 8 points

(4) Correct graphic solution and proper projections
(2) Correct horizontal and frontal projections of shaft centerline
(2) Correct true length of shaft, within limits

General Appearance -- 2 points

(1) All folding lines, developed lines, and planes labeled properly
(1) Neatness, erasures, and cleanliness

Problem #3 (15 points)

Problem Solution -- 12 points

(9) Correct graphic solution and proper projections
(3) Correct true angle between sloping surfaces, within limits

General Appearance -- 3 points

(2) All folding lines and planes labeled properly
(1) Neatness, erasures, and cleanliness

Problem #4 (15 points)

Problem Solution -- 12 points

(5) Correct graphic solution and proper projections
(2) Correct true length of line XY, within limits
(2) Correct bearing of line XY laid off in horizontal projection, within limits
(2) Correct slope of plane, within limits
(1) Correct horizontal and frontal projections of line XY

General Appearance -- 3 points

(2) All folding lines, developed lines and planes labeled properly
(1) Neatness, erasures, and cleanliness

Problem #5 (15 points)

Problem Solution -- 12 points

(10) Correct graphic solution and proper projections
(2) Correct angle between line and plane, within limits

General Appearance -- 3 points

(2) All folding lines, developed lines, and planes labeled properly
(1) Neatness, erasures, and cleanliness

Problem #6 (20 points)

Problem Solution -- 16 points

(8) Correct graphic solution and proper projections
(2) Correct bearing of grade line XY, within limits
(2) Slope of grade line XY developed properly, within limits
(2) Correct true length of grade line XY, within limits
(2) Horizontal and frontal projections of grade line XY shown correctly

Problem #6 (continued)

General Appearance -- 4 points

(3) All folding lines, developed lines, and planes labeled properly
(1) Neatness, erasures, and cleanliness

Problem #7 (10 points)

Problem Solution -- 8 points

(4) Correct graphic solution and proper projections
(1) Point X properly located in the horizontal plane
(1) Correct centerline length of 1 inch diameter shaft, within limits
(1) Correct true angle between shaft centerline and plane
(1) Horizontal and frontal projections of shaft centerline shown properly

General Appearance -- 2 points

(1) All folding lines, developed lines, and planes labeled properly
(1) Neatness, erasures, and cleanliness

UNIVERSITY OF MISSOURI
MECHANICAL ENGINEERING DEPARTMENT
ME 10 DESCRIPTIVE GEOMETRY

EXAMINATION 2

General Directions

1. This examination consists of a series of true-false and multiple choice questions. All answers are to be entered on the answer sheet opposite the corresponding number of the question. DO NOT WRITE ON THE EXAMINATION.

2. Please do not remove the staples from this examination.

3. All answers should be marked with pencil. If an answer must be changed, erase completely and re-mark the item. Do not make any extra marks on the answer sheet.

4. No score will be recorded for this examination unless both the answer sheet and the examination booklet are returned at the completion of the test.

SECTION I - TRUE-FALSE (50%)

Directions: If the statement is true, shade in completely the small circle under the letter "T" opposite the question number on the answer sheet. If the statement is false, shade in completely the small circle under the letter "F" opposite the question number on the answer sheet.

1. If two parallel planes are intersected by a third plane, the lines of intersection are parallel.

2. Two oblique planes may have a profile line as their line of intersection.

3. Two level lines are shown lying in a plane thus causing the plane to be classified as a level plane.

4. A plane may be passed through one given line with the plane parallel to any given second line.

5. Any plane will appear as an edge in that view which shows any line in the plane as a point.

6. It is possible for a horizontal, frontal, or profile line to appear as a point in a third successive auxiliary view.

7. It is not possible for the projections of an angle between two lines to appear greater than the true angle between the lines.

8. A line lying on a plane cannot have a slope less than the slope of the plane itself.

9. An oblique line may be found as a point in a first auxiliary view.

10. A line which appears as a point in a first auxiliary view projected from the side view is called a profile line.

11. When viewing an object through a horizontal plane, the space directions up-down and left-right are involved.

12. An oblique surface forms an acute angle with all of the principal planes of projection.

13. To develop the normal view of a plane the line of sight must be parallel to the edge view of the plane.

14. The bearing of a line may be defined as the angle the line makes with a horizontal plane.

15. A straight line can intersect a plane surface at only one point.

16. If given the top and front views of two oblique lines, their intersection or non-intersection can be definitely determined without the aid of additional views.

17. A view having a direction of sight parallel to a true-length view of the line of intersection of two planes, shows the true size of the dihedral angle.

18. Lines which are perpendicular in space will not necessarily appear perpendicular in all orthographic projections.

19. Non-intersecting, non-parallel lines are referred to as skew lines.

20. Any two lines lying in a plane must either intersect or be parallel.

21. A plane parallel to two non-parallel frontal lines is a frontal plane.

22. A line which is parallel to a plane is parallel to all lines in that plane.

23. The strike line of a plane is the direction of a horizontal line on that plane.

24. The adjacent dihedral angles formed by two intersecting planes are complementary.

25. A line cannot be drawn perpendicular to each of two non-intersecting lines.

<u>SECTION II</u> - <u>MULTIPLE CHOICE</u> (30%)

Directions: Shade in completely the small circle <u>under</u> the letter (A, B, C, or D) of the most nearly correct answer opposite the question number on the answer sheet.

26. Given the horizontal, frontal, and side projections of line AB. One auxiliary view is required to project line AB into true length. Therefore, line AB is:

    A. a frontal line
    B. an inclined line
    C. a normal
    D. none of these

27. A given inclined line is perpendicular to how many of the three principal reference planes?

A. None
B. One
C. Two
D. Three

28. A line which makes an angle of 60 degrees with the horizontal plane and 30 degrees with the frontal plane makes what angle with the side plane?

A. 0 degrees
B. 30 degrees
C. 45 degrees
D. 60 degrees

29. Line AB is inclined to the horizontal and side planes and appears to be vertical in the side plane. Therefore, line AB:

A. can be called a vertical line
B. is a frontal line
C. is a profile line
D. is true length in the horizontal plane

30. The number of units of vertical rise for each one hundred units of horizontal distance is called the:

A. batter
B. incline
C. percent grade
D. percent strike

31. Inclined surface ABC is perpendicular to the frontal plane. Line AC projects as a point in the front view. Line AB is true length in this view. Therefore,

A. Line AB is true length in the horizontal projection
B. Line AC will project true length in the side plane
C. Line CB is true length in the horizontal projection
D. None of these

32. The dip of a plane refers to the angle the plane makes with the:

A. frontal plane
B. horizontal plane
C. inclined plane
D. profile plane

33. Line AB is parallel to the frontal plane. An auxiliary plane used to find the point view of this line would have to be placed perpendicular to the:

    A. frontal plane
    B. horizontal plane
    C. inclined plane
    D. profile plane

34. The view which shows the angle (true size) between two oblique planes will show the line of intersection between the two given planes:

    A. as a point
    B. foreshortened
    C. in true length
    D. none of these

35. The following statements all relate to oblique surfaces. Which statement is <u>not</u> correct?

    A. It requires at least two auxiliary views to project an oblique surface into true size and shape.
    B. Oblique surfaces are always bounded by oblique lines.
    C. Oblique surfaces are always projected as foreshortened views on the principal planes.
    D. An oblique surface will not project as an edge in any of the principal planes.

36. Any view projected from the true size view of a plane will show:

    A. the plane again in true size
    B. the plane as an edge
    C. the plane foreshortened
    D. none of these

37. The perpendicular distance of a point to an oblique plane may be measured in a view showing the:

    A. frontal plane as an edge
    B. horizontal plane as an edge
    C. oblique plane as an edge
    D. plane in true size

38. A line that is perpendicular to the horizontal plane projects:

    A. as a vertical line in the front view
    B. as a vertical line in the side view

C. parallel to folding line 2/3 in the front view
D. all of these

39. Line AB is drawn parallel to folding line 1/2 in the top view and projects as an inclined line in the front view. Therefore, line AB:

A. is true length in the side view
B. is inclined to two of the principal projection planes
C. is true length in the horizontal view
D. none of these

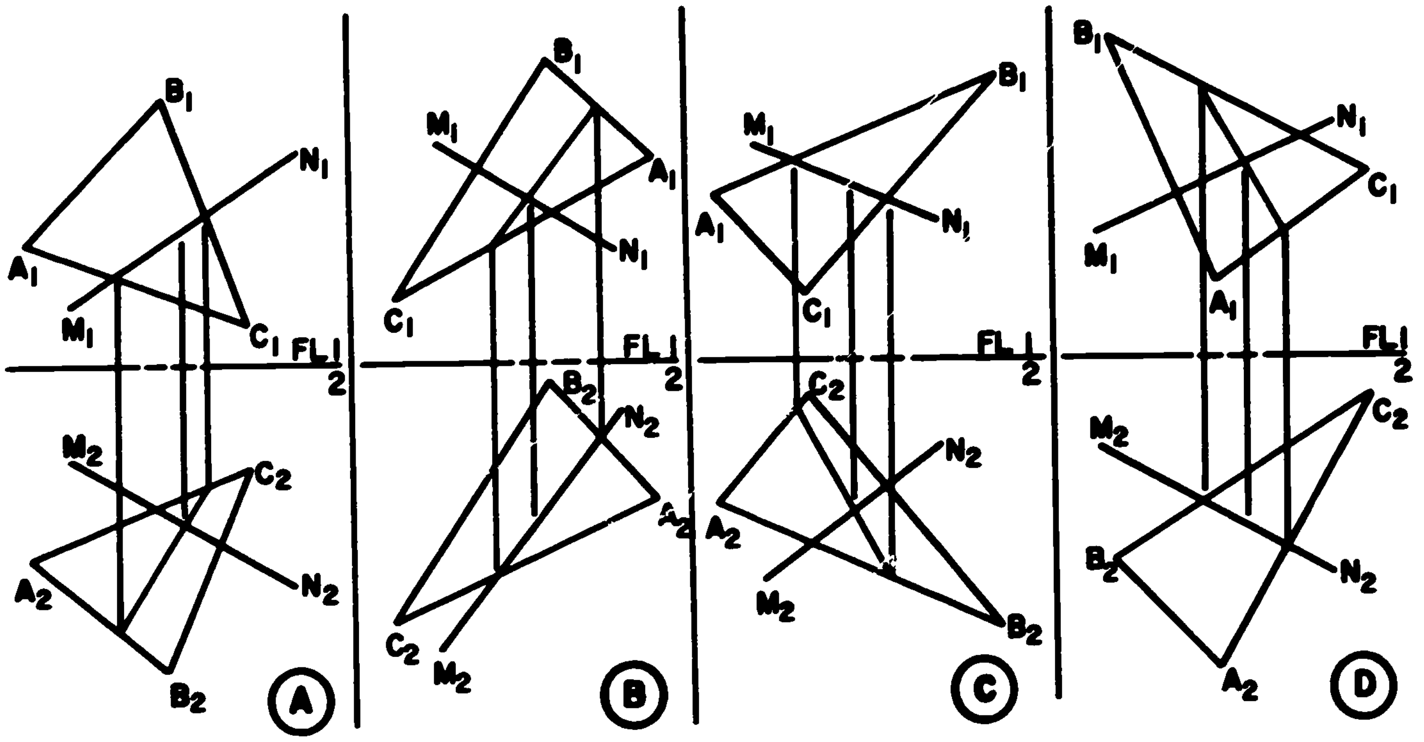
40. To develop a view showing a line in true length, the projection plane must be:

A. inclined to the line
B. parallel to the line
C. perpendicular to the line
D. none of these

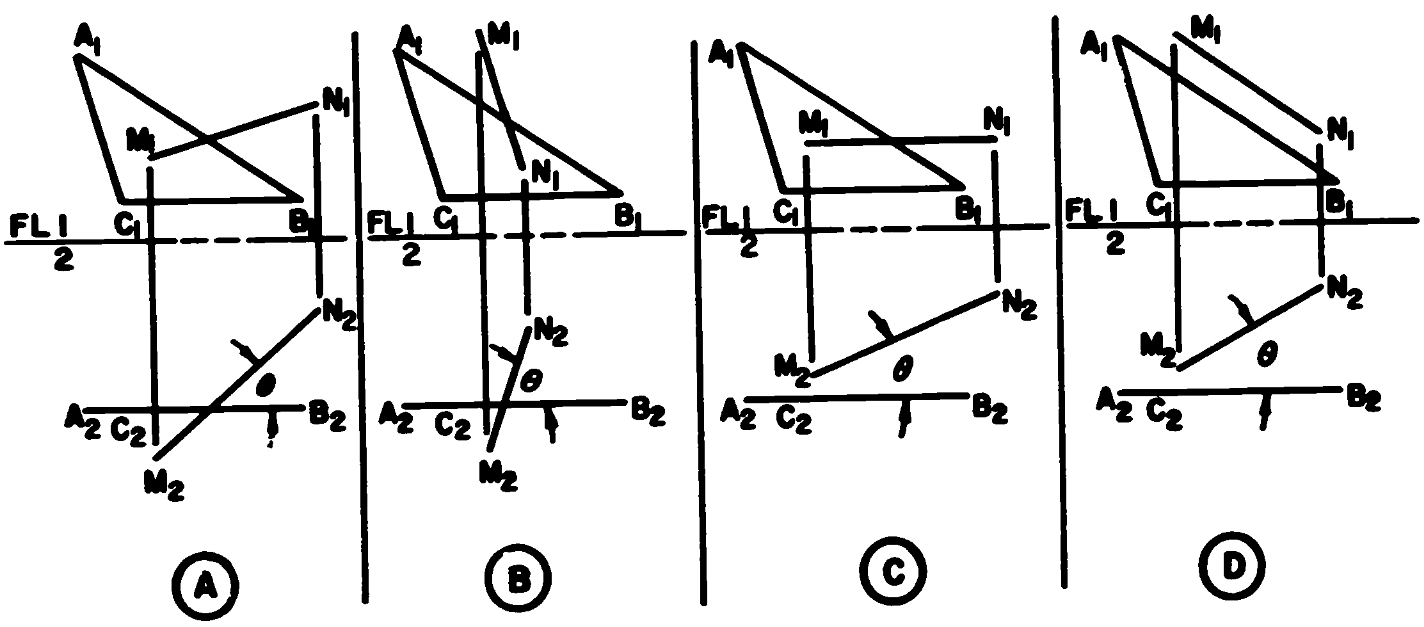
SECTION III - MULTIPLE CHOICE (VISUALIZATION ITEMS) (20%)

Directions: Read the items and select correct answers from a series of illustrations. One or more answers in the series may be correct. Shade in completely the small circle under the letter (A, B, C, or D) of each correct answer opposite the question number on the answer sheet.

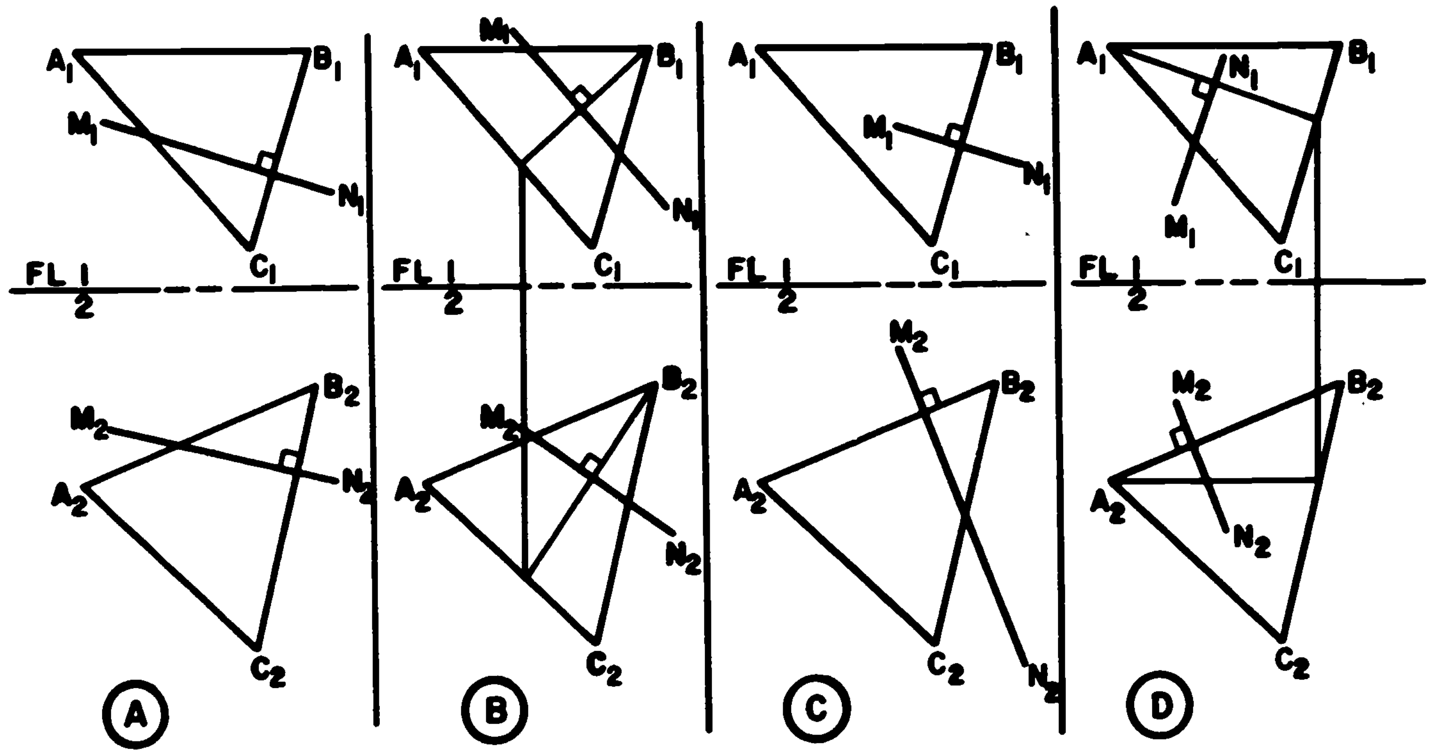
41. Indicate which of the drawings below correctly shows the piercing point of line MN with plane ABC. One or more of the illustrations may be correct.



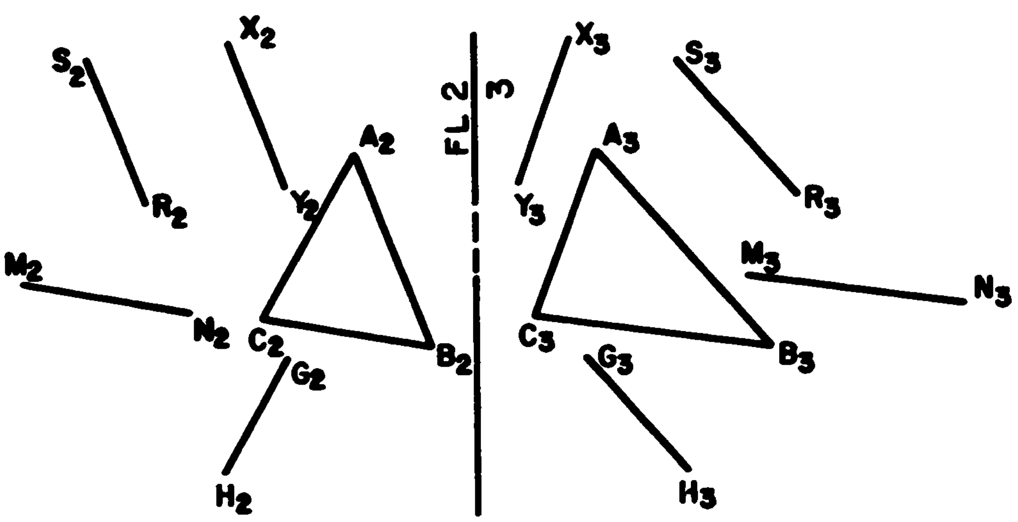
42. Indicate which of the drawings below correctly shows the true angle that line MN makes with plane ABC. One or more of the illustrations may be correct.



43. GIVEN: Line MN perpendicular to plane ABC.
REQ'D: Which of the drawings below shows this relationship correctly? One or more of the illustrations may be correct.



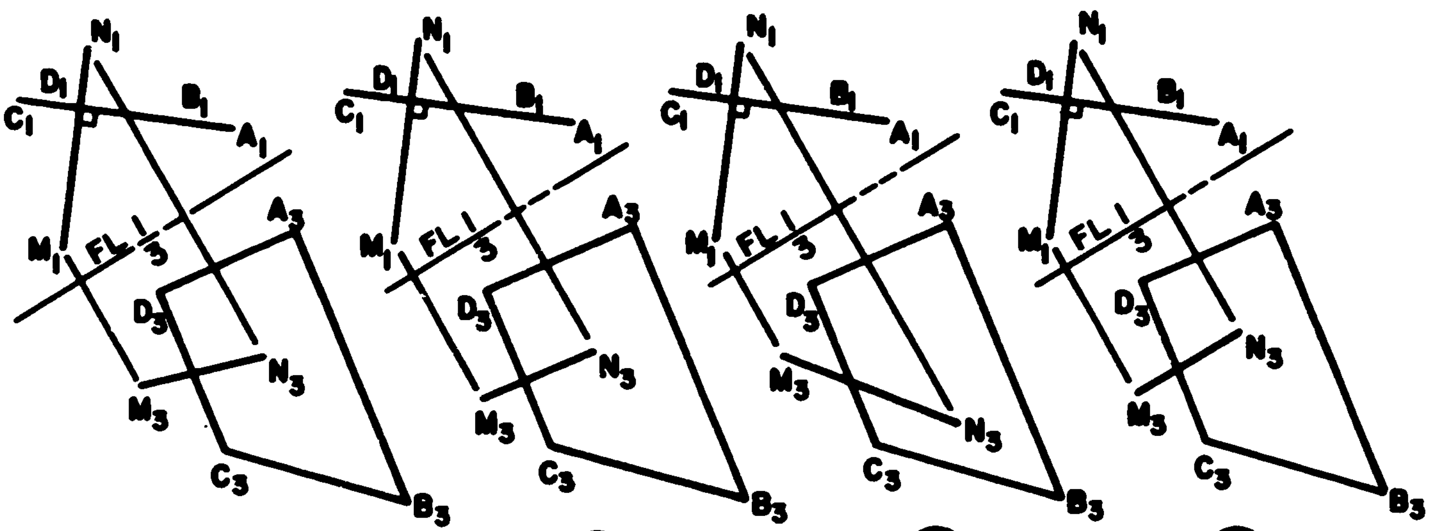
44. GIVEN: The front and right side views of several lines and plane ABC.
REQ'D: Indicate which of the lines is parallel to plane ABC. One or more of the lines may satisfy this condition.



(A) = SR (B) = MN (C) = XY (D) = GH

45. GIVEN: Four illustrations showing the horizontal and first auxiliary views of plane ABCD and line MN.

REQ'D: Indicate which of the drawings below correctly shows line MN perpendicular to plane ABCD. One or more of the illustrations may be correct.



(A) (B) (C) (D)

UNIVERSITY OF MISSOURI
MECHANICAL ENGINEERING DEPARTMENT
ME 10 DESCRIPTIVE GEOMETRY

NAME________________________ SECTION____________

STUDENT NUMBER________________________ DESK____________

GRAPHIC PROBLEM PERFORMANCE

EXAMINATION 3

FORM A

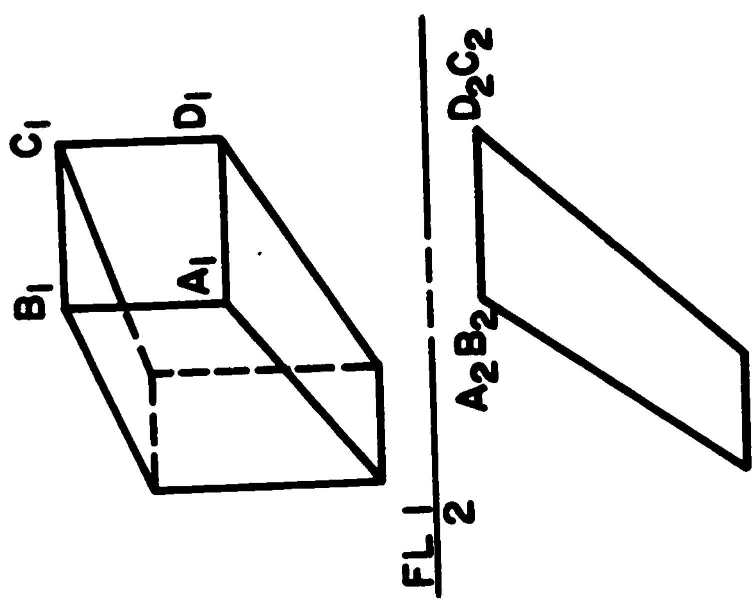
General Directions

This is a performance examination designed to measure your ability to solve graphic problems in Descriptive Geometry. It consists of three (3) problems to be completed according to the instructions given with the problems. Read carefully the instructions for each problem before beginning to work on the problem. You will have one period (50 minutes) for the completion of the examination.

PROBLEM 1. (15%)

The offset chute is to be fabricated from two pieces of sheet steel. corners running down from point B and D will be welded. Determine the angle of bend of corners running down from points A and C.

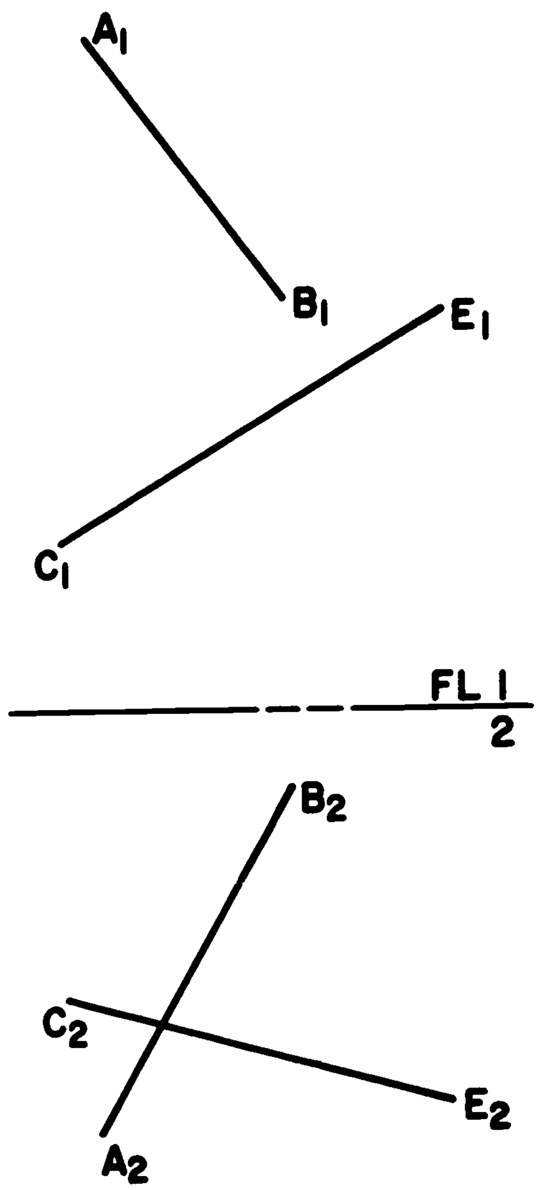
Corner A = ______ Corner C = ______

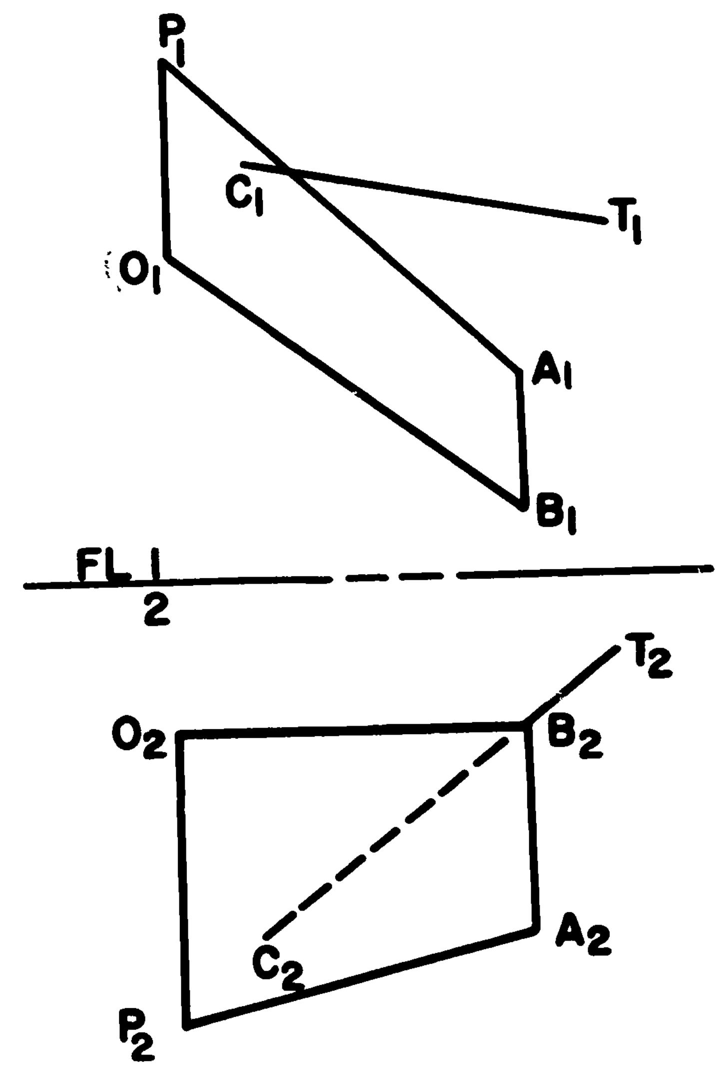


PROBLEM 2. (20%) Scale: 1' = 30'

Determine the true length, bearing and show all views of the shortest tunnel connecting tunnels AB and CE and having a 20% downgrade from AB to CE.

T-L = ______ Bearing = ______





PROBLEM 3. (15%)

Strut TC will be welded to a clip angle which in turn will be welded to surface ABOP. One leg of the clip angle will lie on the surface and the other leg will be parallel to the longitudinal axis of the strut. The bend line of the clip angle will be perpendicular to TC. Determine the angle of bend for the clip angle.

Angle = ________

UNIVERSITY OF MISSOURI
MECHANICAL ENGINEERING DEPARTMENT
ME 10 DESCRIPTIVE GEOMETRY

NAME______________________________ SECTION______________

STUDENT NUMBER______________________ DESK______________

GRAPHIC PROBLEM PERFORMANCE

EXAMINATION 3

FORM B

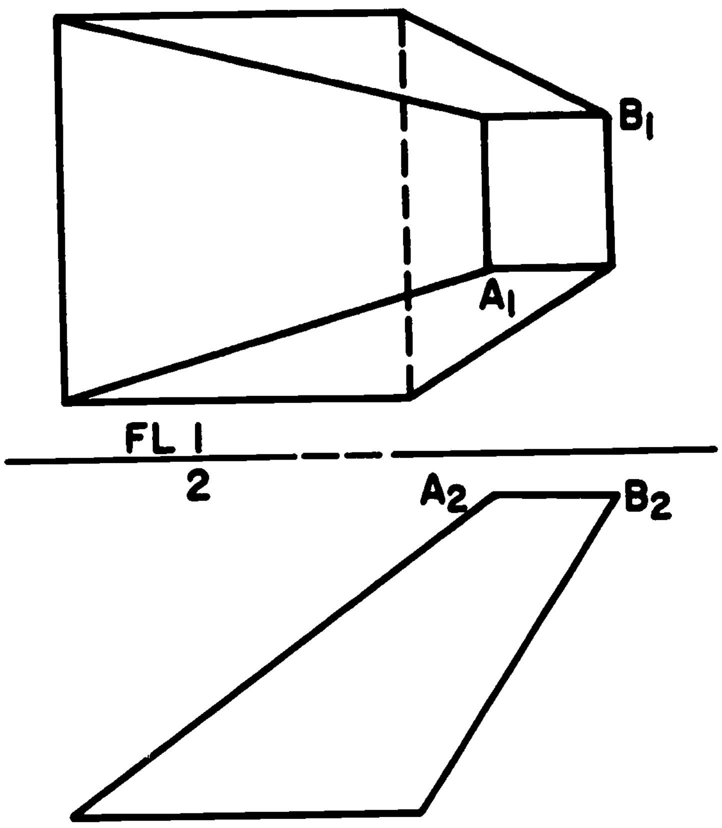
General Directions

This is a performance examination designed to measure your ability to solve graphic problems in Descriptive Geometry. It consists of three (3) problems to be completed according to the instructions given with the problems. Read carefully the instructions for each problem before beginning to work on the problem. You will have one period (50 minutes) for the completion of the examination.

PROBLEM 1. (15%)

Determine the angle of bend of the corners running down from points A and B of the sheet metal transition unit.

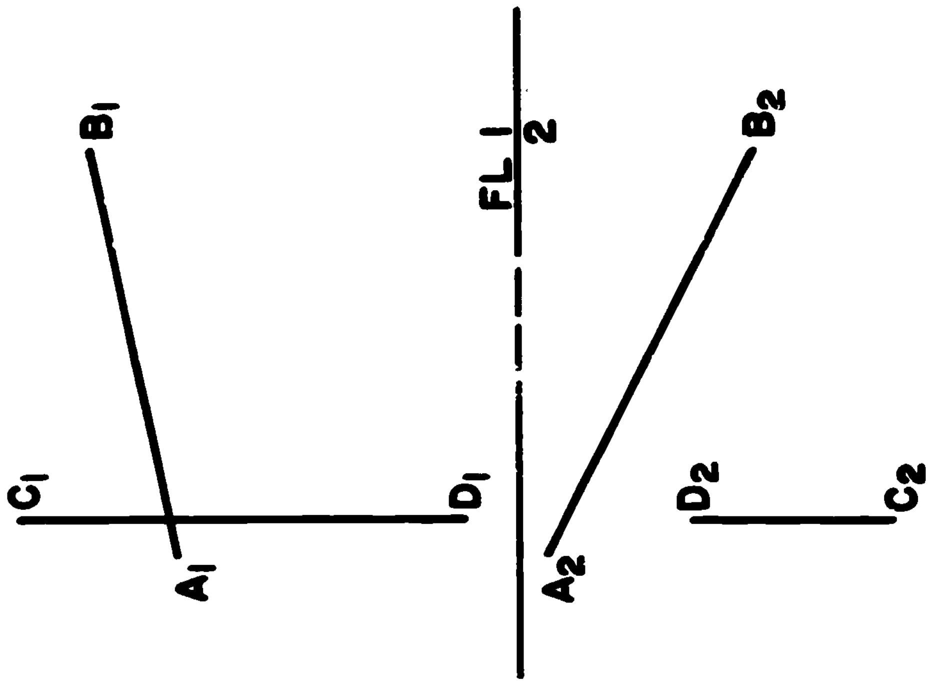
Corner A = ______ Corner B = ______



PROBLEM 2. (20%) Scale: 1" = 60'

Segments of two mining tunnels are shown. Determine the true length, bearing and show all views of the shortest tunnel connecting tunnels AB and CD and having a 60% grade.

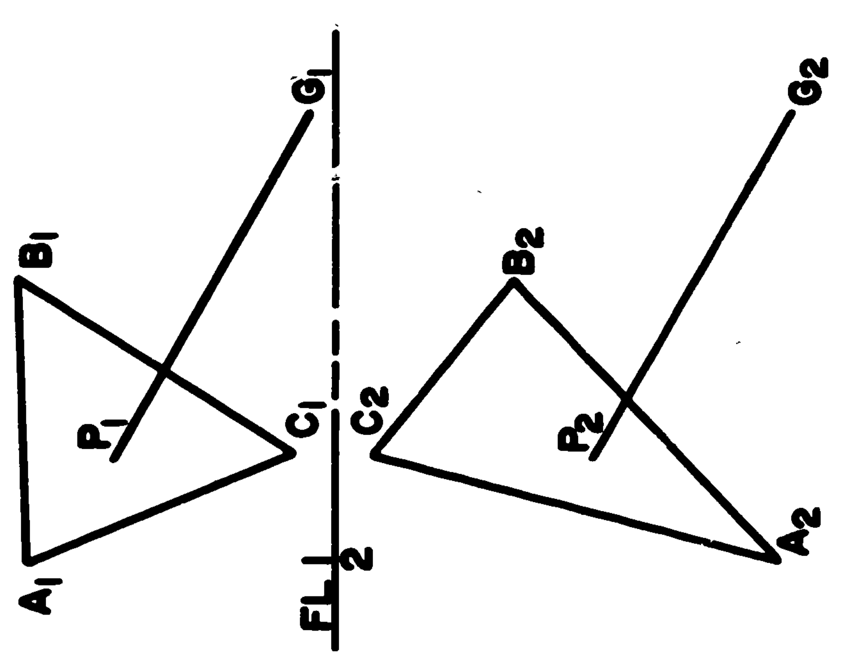
T-L = ________ Bearing = ________



PROBLEM 3. (15%)

Plane ABC represents a corner brace (gusset plate) on a TV tower. A guy wire is to be attached to the tower at point P and fastened to the ground at point G. The angle between the guy wire and the plate must be determined in order to compute the force acting on the guy wire. Determine this angle.

Angle = ________



CRITERIA FOR EVALUATION

Problem #1 (15 points)

Problem Solution -- 12 points

(8) Correct graphic solution and proper projections
(2) Correct dihedral angle for corner running down from point A
(2) Correct dihedral angle for corner running down from point B

General Appearance -- 3 points

(2) All folding lines and planes labeled properly
(1) Neatness, erasures, and cleanliness

Problem #2 (20 points)

Problem Solution -- 16 points

(8) Correct graphic solution and proper projections
(2) Correct true length of shortest tunnel having a specified grade, within limits
(2) Correct bearing of shortest tunnel having a specified grade, within limits
(2) Specified grade of shortest tunnel laid off properly, within limits
(2) All projections of the shortest tunnel shown correctly

General Appearance -- 4 points

(3) All folding lines, developed lines, and planes labeled properly
(1) Neatness, erasures, and cleanliness

Problem #3 (15 points)

Problem Solution -- 12 points

(10) Correct graphic solution and proper projections
(2) Correct angle between line and plane, within limits

Problem #3 (continued)

General Appearance -- 3 points

(2) All folding lines, developed lines, and planes labeled properly
(1) Neatness, erasures, and cleanliness

APPENDIX C

Course Outline

Composite Outline by Period

Laboratory Schedule

Homework Assignment Sheet

Description of Film Slides

UNIVERSITY OF MISSOURI
MECHANICAL ENGINEERING DEPARTMENT
COURSE OUTLINE
ME 10 DESCRIPTIVE GEOMETRY

GENERAL OBJECTIVES

The objectives of this course are to provide the student with opportunities to:

1. Improve and extend the ability to visualize three-dimensional objects from two-dimensional drawings.

2. Increase skill and techniques in the application of descriptive geometry principles.

3. Stimulate interest in further study of the principles of descriptive geometry and its relationship to engineering graphics.

4. Afford practice in the solution of engineering problems, both theoretical and practical, through the application of descriptive geometry.

Credit: 3 semester hours

Text and/or Workbooks:

Text: Frank M. Warner and Mathew McNeary, Applied Descriptive Geometry (fifth edition; New York: McGraw-Hill Book Company, Inc., 1959).

Workbooks: Alfred S. Gaskell, Engineering Descriptive Geometry Laboratory Work Sheets (Columbia: Lucas Brothers Publishers, 1966).

Alfred S. Gaskell, Engineering Descriptive Geometry Homework Sheets (Columbia: Lucas Brothers Publishers, 1966).

ME 10 DESCRIPTIVE GEOMETRY

I. Fundamentals

   A. Function of Descriptive Geometry in engineering
   B. Review use of scales
   C. Standards to be used
      1. Lettering
      2. Line weight
      3. Notations

II. Theory of orthographic projection

   A. Definition
   B. Planes of projection
      1. Frontal
      2. Horizontal
      3. Profile
   C. First-angle projection
   D. Third-angle projection
   E. Visualization

III. Primary auxiliary views

   A. Top view auxiliary
   B. Front view auxiliary
   C. Side view auxiliary
   D. Normal view of plane

IV. Lines

   A. Principal lines
   B. True length
   C. Bearing, slope, and grade
   D. Points on lines

V. Planes

   A. Representation of planes
   B. Points and lines in planes
   C. Principal lines in planes
   D. Locus
   E. Space analysis

VI. Successive auxiliary views

A. Construction of successive auxiliaries
B. Point view of a line
C. Edge and normal view of a plane

VII. Piercing points

A. Auxiliary-view method
B. Two-view method

VIII. Intersection of planes

A. Auxiliary-view method
B. Two-view, piercing point method
C. Cutting plane method

IX. Angle between planes

A. Dihedral angle
   1. Line of intersection given
   2. Line of intersection not given
B. Angle between oblique plane and principal plane

X. Parallelism

A. Parallel lines
B. Parallel planes
C. Lines parallel to planes
D. Planes parallel to lines

XI. Perpendicularity

A. Perpendicular lines
B. Plane perpendicular to a line
C. Line perpendicular to a plane
D. Common perpendicular
   1. Point-view method
   2. Plane method
E. Shortest horizontal line connecting two skew lines
F. Shortest line at specified grade connecting two skew lines
G. Projection of a line on a plane
   1. Two-view method
   2. Auxiliary-view method

XII. Angle between line and oblique plane

A. Plane method
B. Line method
C. Complementary-angle method

XIII. Concurrent vectors

A. Definition of terms
B. Concurrent coplanar vectors
   1. Resultant
   2. Resolution of a vector
C. Concurrent non-coplanar vectors
   1. Resultant
   2. Resolution of a force
D. Velocity vectors
E. Relative motion

XIV. Developments

A. Radial-line development
   1. Pyramid
   2. Truncated pyramid
   3. Right-circular cone
   4. Oblique cone
B. Parallel-line development
   1. Truncated right prism
   2. Oblique prism
   3. Right-circular cylinder
   4. Oblique cylinder
C. Triangulation
   1. Objects composed of plane surfaces
   2. Transition pieces
D. Warped and double-curved surfaces
   1. Warped transition pieces
   2. Spheres
   3. Right helicoid

UNIVERSITY OF MISSOURI
MECHANICAL ENGINEERING DEPARTMENT
COMPOSITE OUTLINE
ME 10 DESCRIPTIVE GEOMETRY - FALL SEMESTER 1967

Laboratory 1.	Organization and orientation.
Lecture 1.	Introduction of space analysis - orthographic review. The planes of projection. Plotting of points in space. Auxiliary views. Standard notations. True length of a line.
Homework 1A.	Orthographic drawing review. Plotting of points.
Laboratory 2.	Review problem quiz. Scales, areas, geometry. Plot points.
Homework 1B.	True length of a line.
Laboratory 3.	True length of a line. A line as a point. Application.
Lecture 2.	Bearing and slope. Line terminology. Line identification. Angle a line makes with the front plane.
Homework 2A.	True length, bearing, and slope of a line.
Laboratory 4.	True length, bearing, and slope of a line.
Homework 2B.	True length, bearing, and slope of a line.
Laboratory 5.	True length, bearing, and slope of a line.
Lecture 3.	Projection of a point on a line and a line in a plane. Intersecting lines. Lines forming a plane. A plane as an edge. Slope of a plane. A plane in true size. Line identification.
Homework 3A.	Projections of a point on a line, and a line in a plane. Lines and planes. Plane surface creation.

COMPOSITE OUTLINE (continued)

Laboratory 6.	Intersecting lines. Lines forming a plane. A plane as an edge. Slope of a plane. A plane in true size. Angle between two lines.
Homework 3B.	Slope and true size of a plane.
Laboratory 7.	Plane in true size. Line identification.
Lecture 4.	Perpendicular distance from a point to a line. Perpendicular distance from a point to a plane. Line parallel to a plane. Plane parallel to a line. Perpendicular distance between parallel planes. Perpendicular distance between two lines. Mining terminology. Strike and dip line. Create a specific plane.
Homework 4A.	Perpendicular distance from a point to a line, line and plane method. Perpendicular distance from a point to a plane.
Laboratory 8.	Perpendicular distance from a point to a line. Line parallel to a plane. Plane parallel to a line.
Homework 4B.	A plane parallel to a plane. Perpendicular distance between two parallel planes.
Laboratory 9.	Perpendicular distance from a point to a line. A line parallel to a plane. Perpendicular distance between two lines.
Lecture 5.	Shortest perpendicular line between two skew lines. Review. Shortest level line between two skew lines. Shortest line of specified slope between two skew lines.
Homework 5A.	Review for two-hour examination #1.
Laboratory 10.	Two-hour examination #1.
Homework 5B.	Shortest level line between two skew lines. Shortest line of specified slope between two skew lines.

COMPOSITE OUTLINE (continued)

Laboratory 11.	Shortest level and specified slope lines.
Lecture 6.	Line of intersection of two planes. (Edge and auxiliary view method.) Where a line pierces a plane. (Edge and auxiliary view method.) Dihedral angle between two planes. A line perpendicular to a plane. (Plane as an edge and two-view method.) Visibility of a line. Angle a line makes with a plane. Project a line upon a plane. Solid objects resting upon an oblique plane.
Homework 6A.	Where a line pierces a plane. (Edge and auxiliary view method.) Angle between two planes. A line perpendicular to a plane.
Laboratory 12.	Where a line pierces a plane. (Edge and auxiliary view method.) Line of intersection of two planes. (Edge and auxiliary view method.)
Homework 6B.	A line perpendicular to a plane. Angle a line makes with a plane.
Laboratory 13.	Quiz. Where a line pierces a plane. Angle between two planes. Solid object resting upon an oblique plane surface.
Lecture 7.	Vector quantity representation. Coplanar vector addition. Noncoplanar vector addition.
Homework 7A.	Vector quantity representation. Addition of coplanar vectors.
Laboratory 14.	Vector quantity representation. Addition of coplanar vectors.
Homework 7B.	Noncoplanar vector addition.
Laboratory 15.	Noncoplanar vector addition.
Lecture 8.	Intersection of plane surface solids. Intersection of curved surface solids.

COMPOSITE OUTLINE (continued)

Homework 8A. Review for examination #2.

Laboratory 16. Two-hour examination #2. (Mid-term)

UNIVERSITY OF MISSOURI
MECHANICAL ENGINEERING DEPARTMENT
PERIOD OUTLINE
ME 10 DESCRIPTIVE GEOMETRY - FALL SEMESTER 1967

Monday-Friday Sections

Date			Laboratory	Lecture	Homework
Sept.	22	Fri.	1		1A
	25	Mon.	2	1	
	26	Tue.		2	2A
	29	Fri.	3		2B
Oct.	2	Mon.	4		
	3	Tue.		3	3A
	6	Fri.	5		3B
	9	Mon.	6		
	10	Tue.		4	4A
	13	Fri.	7		4B
	16	Mon.	8		
	17	Tue.		5	5A
	20	Fri.	9		5B
	23	Mon.	10 EXAM #1		
	24	Tue.		6	6A
	27	Fri.	11		6B
	30	Mon.	12		
	31	Tue.		7	7A
Nov.	3	Fri.	13		7B
	6	Mon.	14		
	7	Tue.		8	8A
	10	Fri.	15		8B
	13	Mon.	16 EXAM #2		

UNIVERSITY OF MISSOURI
MECHANICAL ENGINEERING DEPARTMENT
LABORATORY SCHEDULE
ME 10 DESCRIPTIVE GEOMETRY - FALL SEMESTER 1967

LABORATORY PERIOD 1. Class organization and orientation.

a. Organize class. Seating and lockers.
b. Any locker without a padlock on it may be used.
c. Inform students that they MUST have equipment on hand at the beginning of the second laboratory period. (They will need some, including the workbook, for homework preparation for laboratory 2.)
d. Students in ME 10 MUST have a copy of Luzadder for ME 10 classwork.
e. Have students fill out department information sheet.
f. Hand out ED 2050, Student Information Sheet.
g. Present orientation lecture. Sell the students on the importance of this course in Descriptive Geometry, and the value and use to be gained from it.
h. Emphasize the importance of attendance, promptness, and industry.
i. ONLY Dudley or Master combination locks are permitted.
j. No equipment is to be left in the locker unless a padlock is placed on the drawer.
k. Answer questions relative to the course that the students may have.
l. Explain standards to be used.
    1. Lettering. Vertical capitals 1/8" high. Legible.
    2. Line weight.
        a. Outline lines.
        b. Projection and construction lines. Visible light lines.
        c. Centerlines. (light lines)
        d. Folding lines. Medium weight.
m. Explain importance of:
    1. Attendance. (See student information sheet ED 2050)
    2. Homework problems and Study Aid Questions.
    3. Laboratory problems.
    4. Excuse must be presented before any makeup work is permitted.
    5. Examinations.
    6. Visualization and analysis.
    7. Orthographic projection knowledge.
    8. Skill in use of the scales.
    9. Understanding of plane geometry.

LABORATORY SCHEDULE (continued)

n. Tell students to bring their slide rules and textbooks to each class.
o. Turn in ACTUAL number in class to Professor Gaskell IMMEDIATELY after class meets. Do this for BOTH the FIRST and SECOND class meetings.

LABORATORY PERIOD 2. True length of a line.
a. Assign Problem 205 (sheet 305). Auxiliary view illustration.
b. Assign Problem 206 (sheet 306). True length of a line.
c. Assign Problem 207 (sheets 307 and 308). True length application.
d. Assign Problem 208 (sheet 309). True length of a line.

LABORATORY PERIOD 3. True length, bearing, and slope of a line.
a. Assign Problem 209 (sheet 310). True length, bearing, and slope of a line.
b. Assign Problem 210 (sheet 311). True length, bearing, and slope of a line.
c. Assign Problem 211 (sheet 312). True length, bearing, and slope of a line.
d. Quiz 2, last 20 minutes. Use ED W66-2001. Bearing and slope.

LABORATORY PERIOD 4. Line as a point. True length, bearing, and slope application.
a. Assign Problem 212 (sheet 313). A line as a point.
b. Assign Problem 213 (sheet 314). Application.
c. Assign Problem 214 (sheet 315). Bearing and a slope.

LABORATORY PERIOD 5. Lines and Planes.
a. Quiz 3. First 15 minutes. Use ED W66-2002. Bearing and slope.
b. Assign Problem 215 (sheet 316). Intersecting lines. Lines forming a plane.
c. Assign Problem 216 (sheet 317). Lines forming a plane.
d. Assign Problem 217 (sheet 318). Plane as an edge. Slope and true size of a plane.
e. Assign Problem 219 (sheet 320). Plane in true size.
f. Assign Problem 221 (sheet 322). Plane surfaces. Points lying in a plane.

LABORATORY SCHEDULE (continued)

LABORATORY PERIOD 6. Lines and planes.

a. Quiz 4. First 15 minutes. Use ED W66-2003. True size of a plane.
b. Assign Problem 218 (sheet 319). Plane surface application.
c. Assign Problem 222 (sheet 323). Slope of a plane.
d. Assign Problem 220 (sheet 321). Angle between two lines.
e. Assign Problem 223 (sheet 324). Line identification.

LABORATORY PERIOD 7. Lines and planes.

a. Assign Problem 224 (sheet 325). Perpendicular distance from a point to a line. Line method. Application.
b. Assign Problem 225 (sheet 326). Perpendicular distance from a point to a line. Plane method.
c. Assign Problem 226 (sheet 327). Perpendicular distance from a point to a line. Plane method. Application.
d. Assign Problem 227 (sheet 328). Perpendicular distance from a point to a plane. Application.
e. Assign Problem 228 (sheet 329). A line parallel to a plane.
f. Assign Problem 229 (sheet 330). A plane parallel to a plane.

LABORATORY PERIOD 8. Perpendicular distances, points, lines, and planes.

a. Quiz 5. First 10 minutes. Use ED W66-2004. Plane parallel to a plane.
b. Assign Problem 231 (sheet 332). Perpendicular distance between two lines.
c. Assign Problem 232 (sheet 333). Perpendicular distance between two skew lines.
d. Assign Problem 233 (sheet 334). Perpendicular distance between two lines. Application.
e. Assign Problem 234 (sheet 335). Perpendicular distance between two lines. Application.
f. Assign Problem 235 (sheet 336). Perpendicular distance between two lines. Application.

LABORATORY PERIOD 9. Shortest level and specified slope lines.

a. Assign Problem 236 (sheet 337). Shortest level line between two skew lines.

LABORATORY SCHEDULE (continued)

b. Assign Problem 237 (sheet 338). Shortest level line connecting two skew lines.
c. Assign Problem 238 (sheet 339). Shortest line of specified slope connecting two skew lines.
d. Assign Problem 239 (sheet 340). Shortest level line connecting two skew lines. Application.

LABORATORY PERIOD 10. Two-hour examination #1.

LABORATORY PERIOD 11. Where a line pierces a plane. Line of intersection of two planes.
a. Assign Problem 241 (sheet 342). Line of intersection of two planes, one plane as an edge.
b. Assign Problem 242 (sheet 343). Line piercing a plane. Edge method.
c. Assign Problem 244 (sheet 345). Line piercing a plane. Auxiliary plane method.
d. Assign Problem 245 (sheet 346). Line of intersection of two oblique planes. Edge view method.
e. Assign Problem 247 (sheet 348). Line of intersection of two oblique planes. Auxiliary plane method.
f. Assign Problem 243 (sheet 344). Line piercing a plane. Edge method.
g. Quiz 6. Last 10 minutes. Use ED W66-2005. Where a line pierces a plane.

LABORATORY PERIOD 12. Angle between two planes. Solid object resting upon an oblique plane surface.
a. Assign Problem 248 (sheet 349). Dihedral angle between two planes. Application.
b. Assign Problem 249 (sheet 350). Line perpendicular to a plane. Edge view method.
c. Assign Problem 251 (sheet 352). Angle a line makes with a plane. Application.
d. Assign Problem 252 (sheet 353). Solid object resting upon an oblique plane.
e. Assign Problem 253 (sheet 354). Strike and dip of a vein of ore.

LABORATORY PERIOD 13. Coplanar vector addition.
a. Assign Problem 256 (sheet 357). Addition of coplanar vectors.
b. Assign Problem 257 (sheet 358). Addition of coplanar vectors.

LABORATORY SCHEDULE (continued)

LABORATORY PERIOD 14. Noncoplanar vector addition.

a. Assign Problem 259 (sheet 360). Addition of noncoplanar vectors.
b. Assign Problem 260 (sheet 361). Addition of noncoplanar vectors.
c. Assign Problem 261 (sheet 362). Addition of noncoplanar vectors. Application.
d. Assign Problem 9.10.5, page 207 of Warner.

LABORATORY PERIOD 15. Intersection of plane surface solids.

a. Assign Problem 262 (sheet 363). Intersection of plane surface solids.
b. Assign Problem 263 (sheet 364). Intersection of plane surface solids.
c. Assign Problem 264 (E.D. Paper). Intersection of curved surface solids.

LABORATORY PERIOD 16. Two-hour examination #2. (Mid-term)

UNIVERSITY OF MISSOURI
MECHANICAL ENGINEERING DEPARTMENT
HOMEWORK ASSIGNMENT SHEET
ME 10 DESCRIPTIVE GEOMETRY - FALL SEMESTER 1967

HOMEWORK ASSIGNMENT 1A. To be completed before Laboratory 2.

a. Problem 6, sheet 103. True length of a line.
b. Problem 8, sheets 105 and 106. True length of a line.
c. Review Study Aid Questions 2.1 through 2.11.
d. Review Definitions 1 through 18.

HOMEWORK ASSIGNMENT 2A. To be completed before Laboratory 3.

a. Study Definitions 19 through 22.
b. Study Aid Questions 2.12 through 2.28.
c. Problem 9, sheet 107. Bearing, slope and true length of a line.

HOMEWORK ASSIGNMENT 2B. To be completed before Laboratory 4.

a. Review Definitions 19 through 22.
b. Review Study Aid Questions 2.12 through 2.28.
c. Problem 10, sheet 108. Bearing, slope and true length of a line.

HOMEWORK ASSIGNMENT 3A. To be completed before Laboratory 5.

a. Study Aid Questions 2.29 through 2.54.
b. Study Aid Questions 2.1 through 3.22.
c. Problem 13, sheet 110. Projection of a point on a line. Line in a plane.
d. Problem 14, sheet 111. Intersecting lines. Lines forming a plane.
e. Problem 15, sheet 112. Plane surface creation.

HOMEWORK ASSIGNMENT 3B. To be completed before Laboratory 6.

a. Review Study Aid Questions 2.29 through 2.54.
b. Problem 16, sheet 113. Slope and true size of a plane.
c. Problem 17, sheet 114. Plane surface application.
d. Problem 18, sheet 115. Plane surface application.

HOMEWORK ASSIGNMENT 4A. To be completed before Laboratory 7.

a. Study Aid Questions 3.23 through 3.30.
b. Problem 21, sheet 118. Perpendicular distance from a point to a line. Line method.
c. Problem 22, sheet 119. Perpendicular distance from a point to a line. Application.
d. Problem 23, sheet 120. Perpendicular distance from a point to a line. Application.
e. Problem 25, sheet 122. Perpendicular distance from a point to a line. Application.

HOMEWORK ASSIGNMENT SHEET (continued)

HOMEWORK ASSIGNMENT 4B. To be completed before Laboratory 8.

a. Study Aid Questions 3.62 through 3.70.
b. Study Articles 3.44 through 3.46, p. 66 Warner.
c. Problem 26, sheet 123. Construct a line parallel to a plane.
d. Problem 27, sheet 124. Construct a plane parallel to a line.
e. Problem 28, sheet 125. Perpendicular distance between two skew lines. Line method.
f. Problem 29, sheet 126. Perpendicular distance between two skew lines. Plane method.

HOMEWORK ASSIGNMENT 5A. To be completed before Laboratory 9.

a. Study Aid Questions 3.31 through 3.33.
b. Problem 31, sheet 128. Shortest level line.
c. Problem 32, sheet 129. Shortest level line.
d. Problem 33, sheet 130. Shortest line of specified slope.

HOMEWORK ASSIGNMENT 5B. To be completed before Laboratory 10.

a. Review for two-hour examination #1.

HOMEWORK ASSIGNMENT 6A. To be completed before Laboratory 11.

a. Study Aid Questions 3.34 through 3.42.
b. Problem 34, sheet 131. Line piercing a plane. Edge method.
c. Problem 35, sheet 132. Line piercing a plane. Auxiliary plane method.
d. Problem 36, sheet 133. Angle between two lines.
e. Problem 37, sheet 134. Line perpendicular to a plane. Edge method.

HOMEWORK ASSIGNMENT 6B. To be completed before Laboratory 12.

a. Problem 38, sheet 135. Line perpendicular to a plane. Two views only.
b. Problem 39, sheet 136.
c. Problem 40, sheet 137. Angle a line makes with a plane.

HOMEWORK ASSIGNMENT 7A. To be completed before Laboratory 13.

a. Study Aid Questions 5.1 through 5.20.
b. Problem 41, sheet 138. Vector quantity representation.
c. Problem 42, sheet 139. Addition of coplanar vectors.
d. Problem 43, sheet 140. Addition of coplanar vectors.

HOMEWORK ASSIGNMENT SHEET (continued)

HOMEWORK ASSIGNMENT 7B. To be completed before Laboratory 14.

a. Study Aid Questions 5.1 through 5.20. Study review.
b. Problem 44, sheet 141. Addition of noncoplanar vectors.
c. Problem 45, sheet 142. Addition of noncoplanar vectors.
d. Problem 46, sheet 143. Vector addition. Application.

HOMEWORK ASSIGNMENT 8A. To be completed before Laboratory 15.

a. Study Articles 3.24 and 3.25, p. 52 Warner. Line of intersection of plane surfaces.
b. Study Articles 14.24 through 14.27, p. 315 (4th Edition), or Articles 10.24, p. 248 (5th Edition) of Luzadder. Line of intersection of plane surfaces.
c. Study Articles 7.1 through 7.14, p. 143 Warner. Line of intersection of plane surfaces.
d. Problem 47, sheet 144. Line of intersection of plane surfaces.
e. Problem 48, sheet 145. Line of intersection of plane surfaces.

HOMEWORK ASSIGNMENT 8B. To be completed before Laboratory 16.

a. Review for two-hour examination #2. (Mid-term)

GASKELL TEACHING AIDS
13 Thistledown Drive
Columbia, Missouri

DESCRIPTIVE GEOMETRY PROJECTION SLIDES

The Descriptive Geometry Projection Slides are Recommended for:

1. Teacher self-improvement.
2. College courses in Descriptive Geometry.
3. Trade school courses in Descriptive Geometry.
4. High school courses in Descriptive Geometry.
5. Special groups and application.

The Descriptive Geometry Projection Slides consist of a set of 9 units comprising 368 slides, with descriptive notes. Color slides are used to advantage. Starting with basic projection, the slides take up a step by step development of the solution of space problems and applications as taught in the usual Descriptive Geometry course. The slides aid the student greatly in visualizing and understanding the principles involved. Knowledge retention is increased and material presentation is speeded up by the use of these slides. They have proven very successful by actual class use. The presentation is based upon a workable knowledge of orthographic projection.

A Unit description of the slides is as follows:

UNIT D2. AUXILIARY VIEWS. BEARING AND SLOPE. LINE TERMINOLOGY (73 slides)
Principle of auxiliary views. Projection principles. True length, bearing and slope of a line. Types of lines. A complete coverage for starting Descriptive Geometry.

UNIT D3. POINTS, LINES AND PLANES (70 slides)
A full coverage of points and lines in a plane. Plane as an edge and plane in true size. Essential to presentation of lines and planes. Good coverage.

UNIT D4. POINTS, LINES AND PLANES (60 slides)
A continuation of Unit D3. Deals with perpendicularity, parallelism of lines, plane construction, etc. A complete coverage of this area.

UNIT D5. SHORTEST LINE BETWEEN TWO SKEW LINES (21 slides)
A complete coverage of the shortest perpendicular, shortest level, and shortest specified slope line between two skew lines. Very good.

UNIT D6. LINES AND PLANES (31 slides)
Line of intersection of two planes. Line piercing a plane. Angle between two planes. Line perpendicular to a plane. Counter revolution.

UNIT D7. VECTOR QUANTITIES (32 slides)
Definitions, illustration, examples and solutions for Vector quantities. Very good.

UNIT D8. INTERSECTION OF SOLIDS (27 slides)
A good coverage of the line of intersection of plane and curved surface solids. Several methods illustrated.

UNIT D9. APPLIED DESCRIPTIVE GEOMETRY (24 slides)
Tangent method for laying off angles. End cut and angle of twist for pipe and corner iron. Very good application Unit.

UNIT D15. DEVELOPMENT OF LATERAL SURFACES (26 slides)
Step by step illustrations for making developed views of cylinders, cones, pyramids, transition pieces, etc. Very good coverage.

APPENDIX D

Problem Analysis Form

Typical Graphic Problem

Graphic Problem Analysis

Graphic Problem Solution

PROBLEM ANALYSIS FORM
ME 10 DESCRIPTIVE GEOMETRY

Name	Sec.	Prob. No.	Sht. No.	Student No.	Date

A. TYPE OF PROBLEM: ____________________

____

B. FINAL VIEW NEEDED: ____________________

____

____

C. ORDER OF STEPS IN SOLVING PROBLEM:

1. ____________________

____

2. ____________________

____

3. ____________________

____

4. ____________________

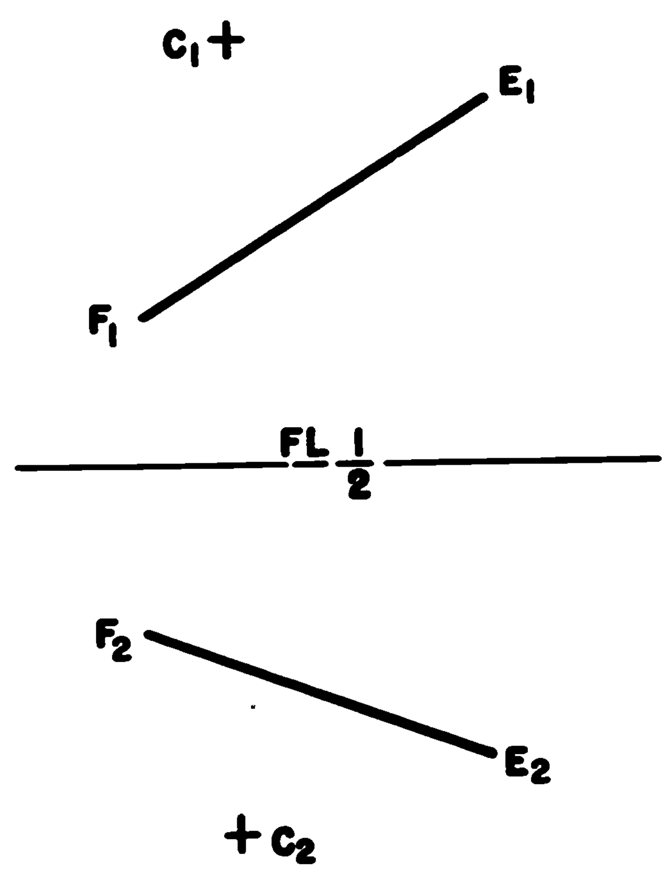
____

5. ____________________

____

D. SKETCH:

223. Perpendicular distance from a point to a line (Line method).
Scale: 6" = 1'-0"
a. Use the line method to determine the true length of the shortest distance from point C to line EF.
b. Show the H and F projections of the shortest distance.



TYPICAL GRAPHIC PROBLEM

DATE	SCALE	NAME	SEC. DESK	DWG. NO.

PROBLEM ANALYSIS FORM
ME 10 DESCRIPTIVE GEOMETRY

Smith, John	B	123	223	119886	9/21/67
Name	Sec.	Prob. No.	Sht. No.	Student No.	Date

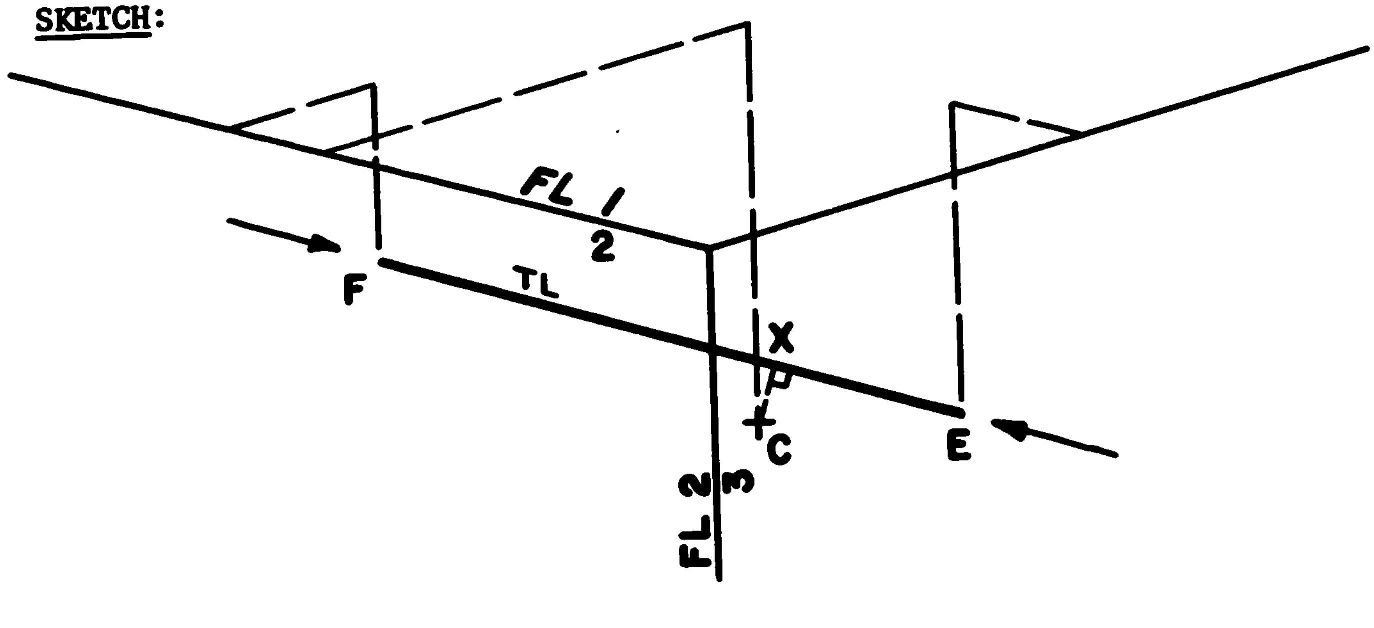
A. TYPE OF PROBLEM: Perpendicular distance from a point to a line.

B. FINAL VIEW NEEDED: The shortest distance from the point to the line will be seen in that view of the point and line where the line also appears as a point.

C. ORDER OF STEPS IN SOLVING PROBLEM:

1. Find the true length of line EF.
2. The shortest connection will be perpendicular to the line in this true length view; however, it will not be in true length.
3. Develop a view showing the given line EF as a point. Also project point C into this view.
4. In this view, a line drawn from point C to the point view of line EF will be in true length, the desired shortest distance.
5. Project the shortest distance from line EF to point C back to the H and F projections.

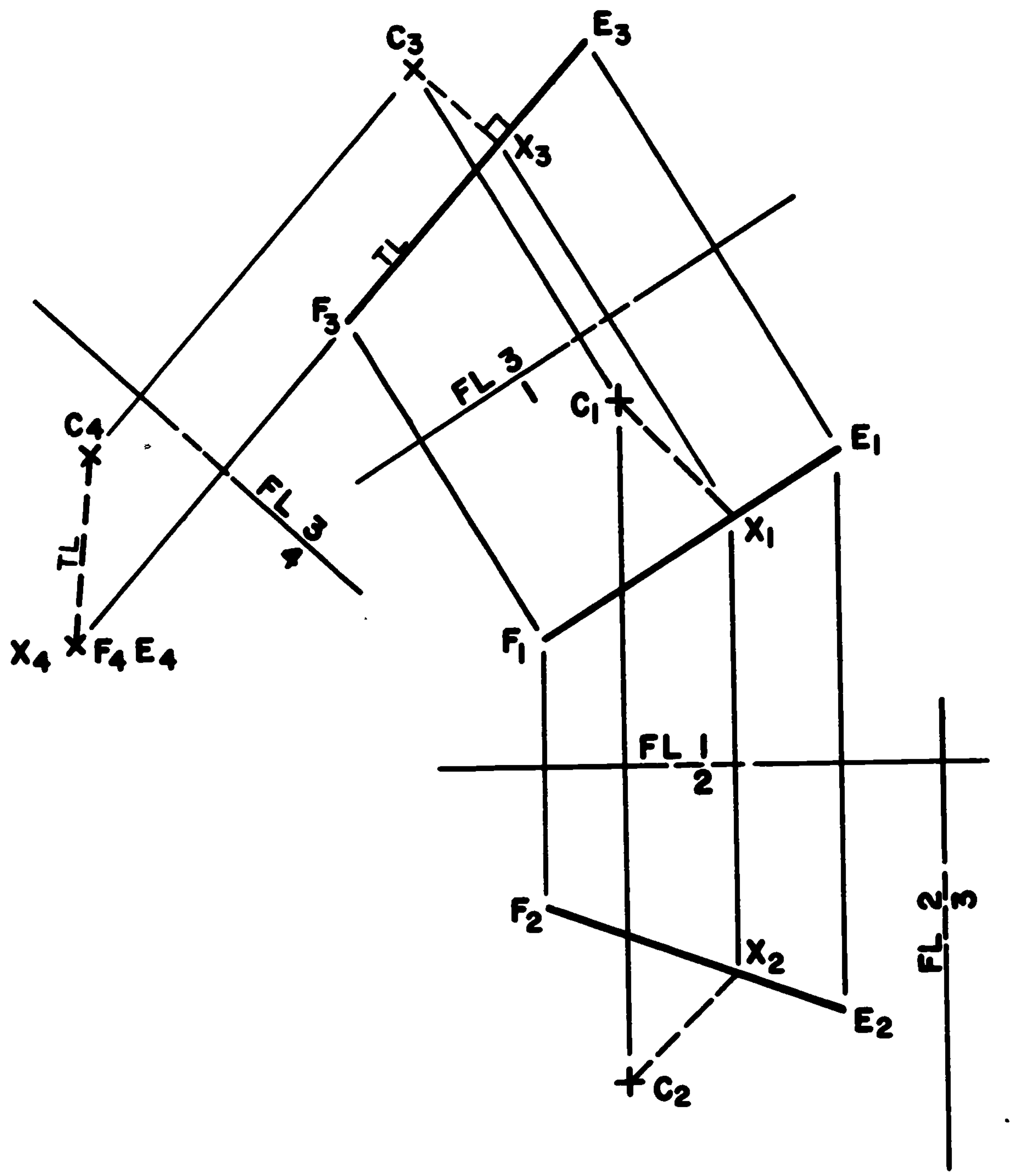
D. SKETCH:



GRAPHIC PROBLEM ANALYSIS

223. Perpendicular distance from a point to a line (Line method).
Scale: 6" = 1'-0"

a. Use the line method to determine the true length of the shortest distance from point C to line EF.
b. Show the H and F projections of the shortest distance.



GRAPHIC PROBLEM SOLUTION

DATE 9-20	SCALE 6" = 1'-0"	NAME SMITH, J.	SEC. B DESK 21	DWG. NO. 223

APPENDIX E

Composite Scores of Initial Status of Students

Comparative Data for Criterion Variables

Comparative Data for Measures of Retention

Attendance Record

COMPOSITE SCORES OF INITIAL
STATUS OF STUDENTS
APPROACH A -- DIRECTED PROBLEM ANALYSIS APPROACH

Student Code	SCAT Score	Knowledge of Dwg. Score	Age	Sem. of College Work Completed
101	42	115	19	2
102	74	109	20	0
103	58	111	18	2
104	47	99	22	4
105	52	72	19	2
106	55	93	19	2
107	38	86	18	2
108	33	81	19	2
109	60	93	18	1
110	32	66	25	6
111	60	116	19	2
112	58	112	18	2
113	58	92	20	4
114	66	97	23	4
115	75	132	18	0
116	50	83	20	4
117	59	130	18	0
118	48	89	19	2
119	57	99	20	4
120	61	113	19	2
121	50	99	18	2
122	53	113	18	0
123	59	106	20	2
124	42	96	18	2
125	47	99	19	2
126	62	88	18	2
127	55	80	20	2
128	43	92	19	2
Means	53.36	98.61	19.32	2.18
SD	10.59	15.84	1.66	1.39
SS	3028.43	6776.68	74.11	52.11
N	28.			

COMPOSITE SCORES OF INITIAL
STATUS OF STUDENTS
APPROACH B -- CONVENTIONAL APPROACH

Student Code	SCAT Score	Knowledge of Dwg. Score	Age	Sem. of College Work Completed
201	57	90	20	4
202	57	115	20	2
203	45	92	20	4
204	54	100	18	2
205	43	108	22	1
206	57	93	18	0
207	50	85	20	4
208	49	110	19	2
209	40	84	18	1
210	53	85	19	2
211	60	94	20	0
212	50	79	20	4
213	55	102	22	6
214	57	89	20	4
215	67	114	19	2
216	49	84	21	6
217	64	96	18	1
218	55	74	21	4
219	45	74	19	2
220	53	74	19	2
221	30	62	25	4
222	51	120	18	0
223	54	79	20	4
224	42	87	18	1
Means	51.54	91.25	19.75	2.58
SD	8.05	14.78	1.65	1.77
SS	1489.96	5022.50	62.50	71.83
N	24.			

DATA FOR COMPARISON OF GRAPHIC PROBLEM SOLVING ABILITY BY DIFFERENTIAL TREATMENT

Directed Problem Analysis		Conventional Approach	
Student Code	Graphic Performance Posttest Score	Student Code	Graphic Performance Posttest Score
101	85	201	83
102	60	202	63
103	80	203	56
104	82	204	54
105	76	205	50
106	90	206	33
107	40	207	59
108	24	208	45
109	64	209	36
110	57	210	75
111	65	211	8
112	72	212	54
113	29	213	75
114	59	214	62
115	96	215	82
116	68	216	55
117	75	217	84
118	32	218	80
119	45	219	65
120	78	220	56
121	56	221	57
122	46	222	92
123	86	223	45
124	34	224	21
125	69		
126	59		
127	48		
128	64		
Mean	62.11	Mean	57.92
SD	19.36	SD	20.45

DATA FOR COMPARISON OF SPATIAL PERCEPTION
BY DIFFERENTIAL TREATMENT

Directed Problem Analysis			Conventional Approach		
Student Code	Spatial Perception Pretest Score	Spatial Perception Posttest Score	Student Code	Spatial Perception Pretest Score	Spatial Perception Posttest Score
101	46	46	201	58	59
102	58	59	202	56	58
103	59	60	203	42	55
104	50	57	204	58	58
105	44	56	205	50	58
106	52	52	206	56	59
107	53	49	207	27	48
108	32	33	208	43	54
109	28	47	209	45	50
110	27	41	210	53	50
111	58	59	211	53	56
112	56	60	212	53	47
113	50	55	213	58	58
114	58	60	214	53	59
115	60	60	215	55	59
116	34	46	216	57	59
117	59	60	217	59	60
118	32	44	218	38	52
119	43	46	219	49	58
120	47	54	220	25	23
121	55	57	221	30	39
122	59	56	222	41	53
123	57	58	223	51	55
124	46	55	224	45	52
125	38	41			
126	58	56			
127	37	48			
128	47	51			
Means	47.96	52.36	Means	48.12	53.29
SD	10.30	7.06	SD	9.82	8.03

DATA FOR COMPARISON OF ABSTRACT REASONING BY DIFFERENTIAL TREATMENT

Directed Problem Analysis			Conventional Approach		
Student Code	Abstract Reasoning Pretest Score	Abstract Reasoning Posttest Score	Student Code	Abstract Reasoning Pretest Score	Abstract Reasoning Posttest Score
101	45	42	201	45	46
102	41	40	202	41	41
103	40	41	203	46	45
104	45	47	204	44	46
105	44	46	205	41	47
106	38	43	206	45	46
107	38	45	207	38	43
108	36	34	208	39	46
109	40	49	209	36	38
110	31	37	210	43	40
111	44	46	211	40	45
112	47	46	212	41	39
113	36	39	213	46	45
114	41	48	214	41	45
115	44	48	215	44	43
116	43	43	216	45	47
117	47	49	217	48	49
118	36	44	218	42	44
119	41	41	219	39	48
120	44	48	220	34	40
121	39	44	221	31	35
122	42	45	222	38	45
123	46	44	223	43	48
124	40	41	224	39	45
125	42	44			
126	47	46			
127	37	43			
128	45	43			
Means	41.39	43.79	Means	41.21	44.00
SD	3.94	3.53	SD	3.97	3.43

DATA FOR COMPARISON OF INFORMATIONAL ACHIEVEMENT BY DIFFERENTIAL TREATMENT

Directed Problem Analysis		Conventional Approach	
Student Code	Informational Achievement Posttest Score	Student Code	Informational Achievement Posttest Score
101	82	201	96
102	94	202	81
103	82	203	67
104	69	204	88
105	82	205	80
106	90	206	83
107	65	207	67
108	66	208	81
109	82	209	61
110	78	210	94
111	82	211	74
112	92	212	81
113	61	213	76
114	84	214	77
115	98	215	85
116	70	216	80
117	87	217	74
118	69	218	76
119	94	219	67
120	90	220	84
121	78	221	49
122	81	222	91
123	77	223	72
124	57	224	60
125	79		
126	67		
127	73		
128	66		
Mean	78.39	Mean	76.83
SD	10.82	SD	11.14

DATA FOR COMPARISON OF ATTITUDE TOWARD DESCRIPTIVE GEOMETRY BY DIFFERENTIAL TREATMENT

Directed Problem Analysis			Conventional Approach		
Student Code	Attitude Pretest Score	Attitude Posttest Score	Student Code	Attitude Pretest Score	Attitude Posttest Score
101	7.7	8.1	201	8.3	7.9
102	7.5	8.1	202	7.7	6.5
103	8.2	7.7	203	8.5	8.1
104	8.1	8.5	204	8.5	7.1
105	8.1	8.5	205	8.5	8.1
106	8.1	8.1	206	8.5	7.9
107	8.5	8.1	207	8.5	8.5
108	8.0	6.5	208	7.9	7.7
109	8.1	8.5	209	8.1	8.1
110	8.5	7.7	210	7.4	6.5
111	8.0	6.0	211	7.7	7.1
112	6.0	8.3	212	6.5	8.5
113	8.5	8.1	213	8.0	8.1
114	8.0	8.5	214	7.7	8.1
115	7.7	7.9	215	7.9	7.9
116	8.3	7.9	216	8.1	6.3
117	8.1	5.8	217	8.2	8.1
118	7.7	8.5	218	8.0	7.7
119	8.5	4.7	219	8.3	8.1
120	7.7	8.5	220	8.5	8.3
121	8.1	8.1	221	8.9	8.5
122	8.1	8.1	222	8.5	8.1
123	8.5	8.3	223	8.5	8.1
124	8.1	7.7	224	8.2	8.3
125	7.7	7.9			
126	7.7	8.5			
127	8.0	7.7			
128	8.2	6.0			
Means	7.99	7.72	Means	8.12	7.82
SD	.474	.968	SD	.485	.627

DATA FOR COMPARISON OF THE RETENTION OF GRAPHIC PROBLEM SOLVING ABILITY BY DIFFERENTIAL TREATMENT

Directed Problem Analysis			Conventional Approach		
Student Code	Graphic Performance Posttest Score	Graphic Performance Retention Test Score	Student Code	Graphic Performance Posttest Score	Graphic Performance Retention Test Score
101	88	68	201	90	82
102	60	58	202	66	40
103	98	66	203	64	44
104	100	96	204	50	46
105	86	84	205	50	26
106	98	64	207	50	60
107	30	28	208	54	46
108	34	32	210	90	80
109	60	74	211	12	28
110	66	18	212	56	60
111	58	60	213	92	68
112	76	82	214	58	70
113	18	40	215	96	86
114	62	76	216	42	64
115	100	96	217	100	84
116	58	72	218	100	66
117	66	96	219	56	62
118	44	54	220	82	64
119	30	46	221	92	40
120	88	68	222	98	96
121	56	94	223	38	74
122	28	62	224	14	12
123	94	94			
124	18	32			
125	66	70			
126	54	62			
127	54	56			
128	52	46			
Means	62.21	64.07	Means	65.91	59.00
SD	24.76	21.45	SD	26.25	21.08

DATA FOR COMPARISON OF THE RETENTION OF TECHNICAL INFORMATION BY DIFFERENTIAL TREATMENT

Directed Problem Analysis			Conventional Approach		
Student Code	Technical Information Posttest Score	Technical Information Retention Test Score	Student Code	Technical Information Posttest Score	Technical Information Retention Test Score
101	82	78	201	96	90
102	94	92	202	81	83
103	82	82	203	67	68
104	69	78	204	88	86
105	82	89	205	80	82
106	90	89	207	67	67
107	65	68	208	81	75
108	66	61	210	94	79
109	82	80	211	74	75
110	78	86	212	81	86
111	82	80	213	76	68
112	92	92	214	77	82
113	61	78	215	85	78
114	84	73	216	80	81
115	98	96	217	74	84
116	70	68	218	76	79
117	87	90	219	67	69
118	69	80	220	84	77
119	94	90	221	49	70
120	90	88	222	91	93
121	78	78	223	72	77
122	81	81	224	60	66
123	77	81			
124	57	53			
125	79	78			
126	67	82			
127	73	59			
128	66	55			
Means	78.39	78.75	Means	77.27	77.95
SD	10.62	11.16	SD	10.79	7.48

RECORD OF ABSENCES

Directed Problem Analysis (Approach A)		Conventional Approach (Approach B)	
Student Number	Days Absent	Student Number	Days Absent
201	0	101	0
202	3	102	0
203	0	103	2
204	0	104	0
205	0	105	5
206	0	106	5
207	0	107	0
208	4	108	1
209	0	109	4
210	0	110	0
211	0	111	3
212	0	112	2
213	0	113	0
214	2	114	1
215	0	115	0
216	0	116	1
217	0	117	0
218	0	118	0
219	0	119	0
220	0	120	0
221	0	121	0
222	0	122	0
223	0	123	0
224	0	124	0
225	0		
226	0		
227	2		
228	0		
Total Absences	11	Total Absences	24
Students	28	Students	24

Mean Absences Per Student = 35/52 = .67

VITA

Eugene Jerome Beck

Born: January 13, 1929, Oshkosh, Wisconsin

Education: Elementary, St. Vincents Parochial School, Oshkosh, Wisconsin, 1935-1943; Secondary, Oshkosh High School, Oshkosh, Wisconsin, 1943-1947; College, Stout State University, Menomonie, Wisconsin, 1953-1956, B. S. in Industrial Education; Stout State University, Menomonie, Wisconsin, part-time 1956-1964, M. S. in Vocational Education; Colorado State University, Fort Collins, Colorado, summer, 1965; University of Missouri - Columbia, summers, 1966-1967, regular sessions, 1966-1967 and 1967-1968.

Teaching Experience: Instructor of drafting, Beloit Vocational and Adult School, Beloit, Wisconsin, 1956-1960; Instructor in Mechanical Design, Oshkosh Technical Institute, Oshkosh, Wisconsin, 1960-1964; Instructor of Pre-engineering Education, Wisconsin State University - Oshkosh, 1964-1966; Assistant Professor of Pre-engineering Education, Wisconsin State University - Oshkosh, on sabbatical leave 1966-1968; Instructor of Mechanical Engineering (one-half time), University of Missouri - Columbia, 1967-1968.

Military Experience: Served with the Eleventh Airborne Division, United States Army, January, 1951 to January, 1953; Honorably discharged, January, 1953.