The Journal of Engineering Drawing

CONTENTS

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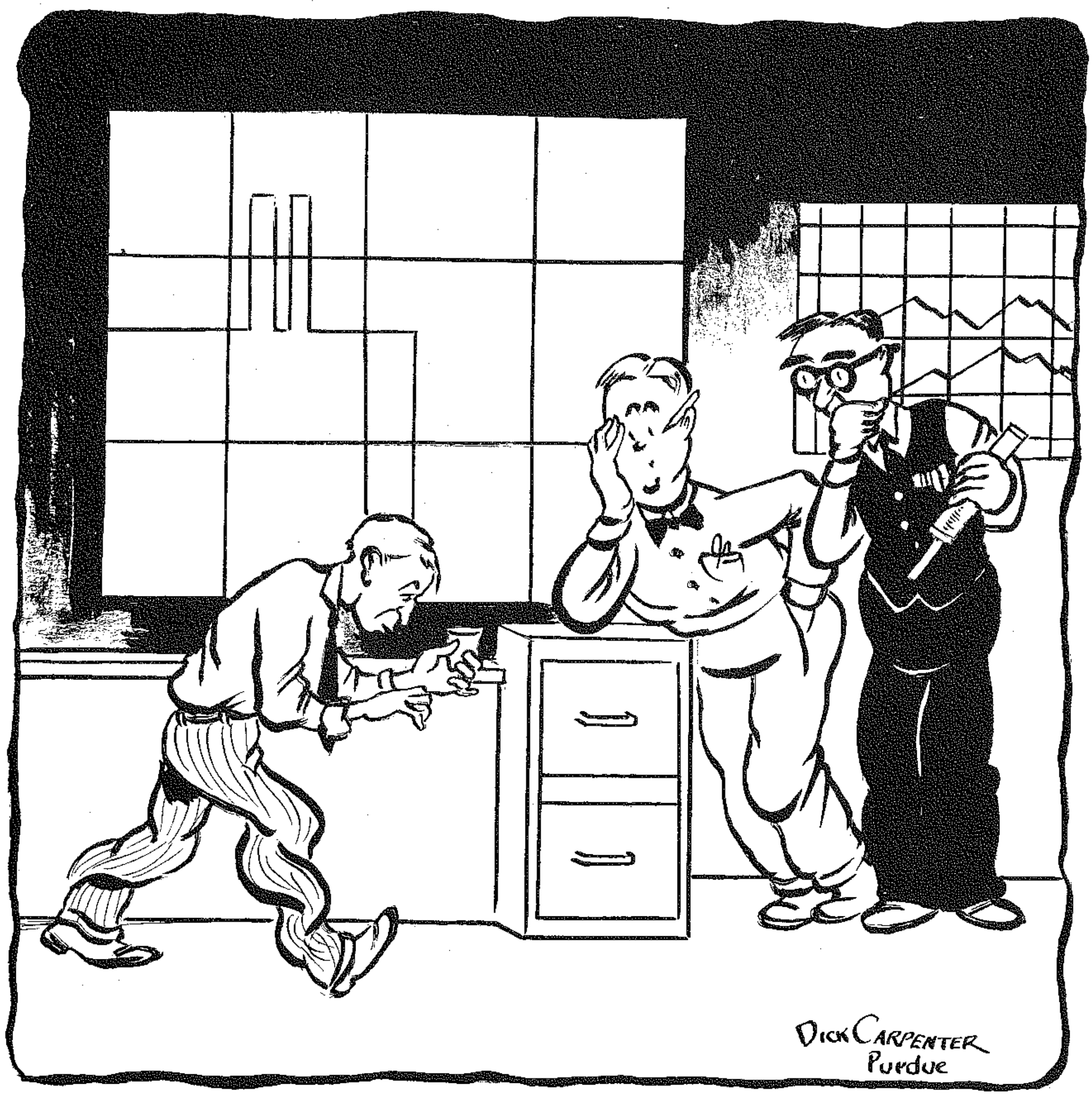
LIFE'S MESSY MOMENT



"Do you suppose Jenkins could be hinting he's been on the board about long enough?

THE MEN ON THE BOARDS

by
E. A. Kehoe
Rochester Products Division
General Motors Corporation

A true human equation?

$$\frac{\text{drafting}}{\text{engineer}} = \frac{\text{interning}}{\text{doctor}}$$

There is a trend during today's shortage of engineers for recent graduates to short-cut the drafting and design room. Expedient as this now may seem to industry, and opportunistic as it may look to the young engineer, by-passing this important career-development phase may be to the long-range detriment both of industry and of young engineers as well.

An engineering drawing is the graphic language by which designers and engineers convey to others their ideas and instructions for the making of tools and products and the building of machines and structures. Unlike an artist's pictorial representation of an object or structure, the engineering drawing does not always show the object or structure as it would appear to the eye; consequently, this drawing can only be read and understood by those trained in this graphical language.

Because it is the basic method upon which all designing and subsequent manufacture is based, every engineer must know how to make and read engineering drawings. It certainly is not a language to be learned only by the comparatively few draftsmen who will be professional writers of it, but rather it must be thoroughly understood by all who are connected with technical industry.

Any language, be it English, German, French, Latin, or any of the others, cannot be read and thoroughly understood without the ability to write it. Words read without an appreciation of their real meanings certainly cannot convey to the reader's mind what the writer intended. If, on the other hand, the word meaning is completely understood, there is no reason why those words cannot be arranged and associated with one and another to form phrases and sentences which convey ideas to others. It cannot be a one-way street.

So it is with the graphical language of the engineering drawing. It is virtually impossible for the engineer to be able to read without being able to write the language. It, also, must be a two-way street. There are those who believe that it is possible to read a drawing without being able to draw one. There are even some schools that offer courses in blueprint reading, presumably designed for mechanics. While these courses undoubtedly serve a useful purpose, and while it will be conceded that some people may be able to read a drawing without being able to draw one, it could well turn out to be a case of a little knowledge being a very dangerous thing. It is a situation in which no engineer can afford to place himself, since his is the responsibility for design and interpretation. To prepare himself for this responsibility, it would be desirable for the engineering student to take all the courses in mechanical drawing and descriptive geometry offered by his school, and to enter industry by way of the drafting room.

CLASSIFICATIONS OF DRAFTING ROOM PERSONNEL

A good drafting room should probably be composed of four groups or classifications of people. One group may consist of men or women who have had little or no formal training, but because of a particular talent or liking for drafting have been brought in under some type of scheduled training program. Another group would consist of what may be called professional draftsmen. These are men who have chosen drafting as a profession and have prepared themselves for the profession by taking the prescribed courses in mechanical drawing, descriptive geometry, strength of materials, mathematics, and mechanics at some technical school. These men are the backbone of the drafting room, the men upon whose shoulders rests the responsibility for putting into graphical language the ideas of the designer and the theoretical and practical solutions of the engineer. The third group may consist of graduate engineers who, initially, are much better equipped theoretically and technically than professional draftsmen, but would do the same type of work. It is this group, however, which may be expected to produce the greatest percentage of the fourth group, the designers. By this it is not meant to imply that the design group is beyond the reach of the men in the first two groups or classifications. There are no barriers to initiative and the acquisition of knowledge, and if a man from either of these first two groups displays the qualifications, he will most certainly be presented with the opportunity to become a designer.

Finally, it would be the design group which would create future design engineers. These are the men who, from training and experience, possess the knowledge and technique to develop the theory and tell others how to design the products of tomorrow. Because it is from here that all industry stems, it is the door to industry that offers the young graduate engineer the greatest opportunities for advancement.

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The Journal is available regularly only to engineering educators and technical libraries.

Not too many years ago, when his services were not in such great demand as they are today, this was often the engineering graduate's only open door to industry. More recently, with the great shortage of engineering talent, industry has been forced to absorb young engineers into their organizations without this basic post graduate training. While it is generally recognized that this procedure is not a desirable one for either industry or the engineer, it has been the lesser of two evils. An extended continuation of this procedure, however, may result in industry being staffed with engineers lacking one of the basic tools of the profession. The situation is analogous to eliminating the internship from the requirements of the medical profession. While at first the engineering graduate may feel that he has eliminated a rather unimportant part of his training and has immediately been placed in a position where he can use his talents to the best advantage, he may regret after a few years his lack of this basic tool. He may even have the unfortunate experience of seeing younger men so equipped steadily approach and surpass him in position and prestige. Therefore, it behooves both the engineering student and industry to take a long hard look at this situation; both have much to gain.

Theorizing upon and pointing out the disadvantages of shortcutting board work are desirable and necessary, but leave the situation none-the-less existent. To this end, most industries have instituted training programs of one sort or another in the hope that they will bridge this gap in the drafting room. Actually, these training programs and their administration have become one of the most important responsibilities of management.

OPERATIONS OF THE DRAFTING ROOM

Perhaps a good way to describe a typical drafting room would be to outline, in principle, how a trainee draftsman and then a professional draftsman would ultimately reach the status of a senior designer, a project engineer, or a position of higher level in engineering (Fig. 1). It is assumed that the prospective trainee has had some training in mechanical drafting of high school level or greater, together with a genuine interest in this type of work. The training program as applied to the individual, of course, varies in detail depending upon the inherent ability of the trainee, his interest, the extent to which he applies himself to the acquisition

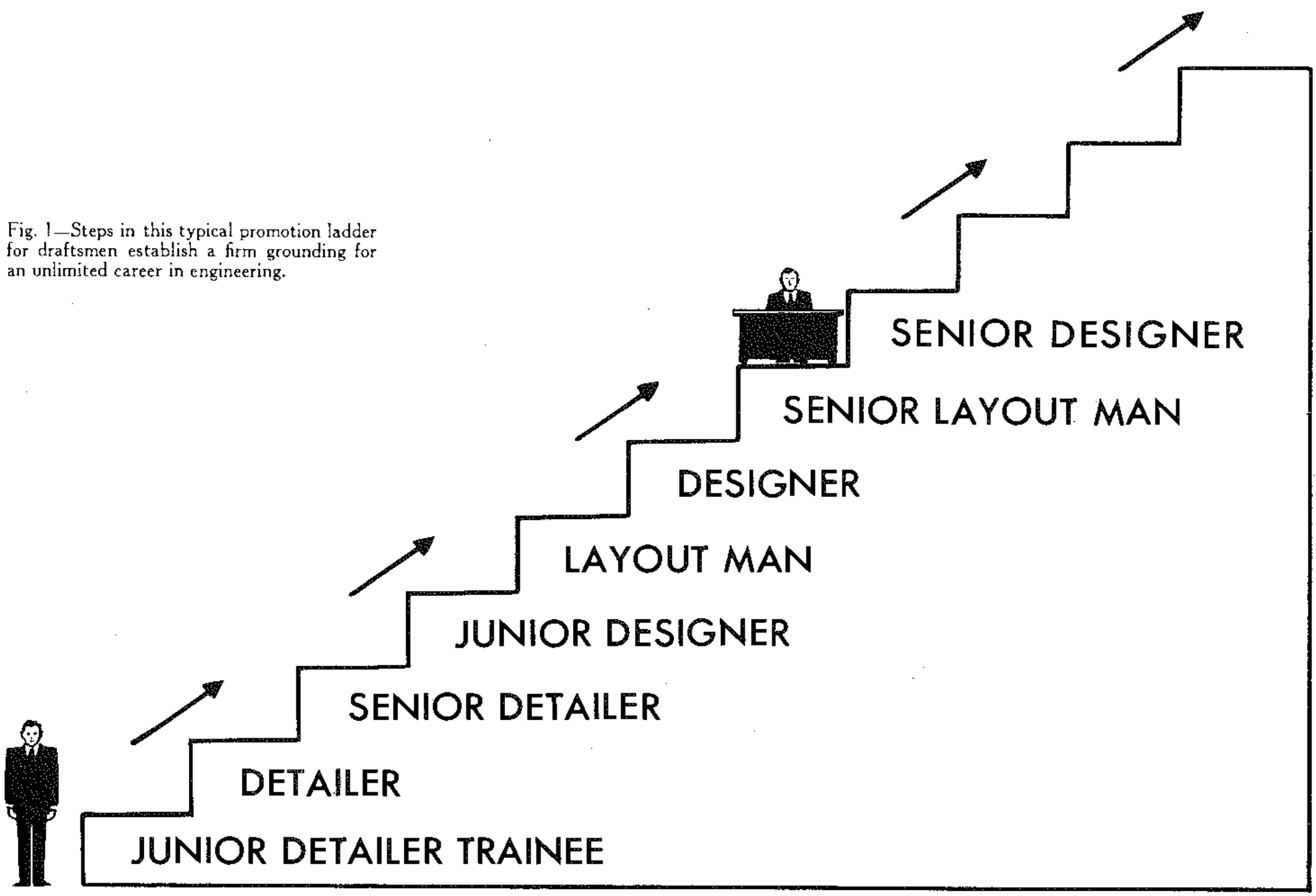


Fig. 1—Steps in this typical promotion ladder for draftsmen establish a firm grounding for an unlimited career in engineering.

of technical knowledge, his ability to work with others, and his personality characteristics.

Initially, the program should start with training in the blueprint vault. This acquaints him with the sizes and use of tracings, the filing and record systems, the operation of blueprint, and various tracing reproduction equipment. These things are all very important to the overall engineering department function even though they may not be immediately apparent to the trainee.

The second part of the program should include training in the engineering records department. Here is where he acquires a knowledge of the procedures and the necessity for new product releases, new drawing releases, change requests, change notices, methods of part number assignments for both experimental and production parts, and the distribution of prints to various departments. This phase of the work represents the business methods which are necessary to keep engineering records and to insure the prompt distribution of correct information to the various manufacturing and service departments of the company.

At the conclusion of these two preparatory periods, the trainee is assigned a drawing board and is given the opportunity to express ideas and instructions in the form of the engineering drawing. To begin with, the trainee's drawing assignments are strictly of an elementary nature, and he is constructively criticized by the checker and the chief draftsman.

As the trainee shows progress in his ability to make good elementary drawings accurately and quickly, he is given detail drawing assignments. This type of assignment involves progressively the drawing of simple and then complicated parts or groups of parts in assemblies.

Proficiency in this type of work leads to drawing assignments involving small layouts, and the trainee may be classified at this time as a junior layout man. It is at this time especially that he should be urged to acquire, either by himself or through formal training in night or correspondence school, a working knowledge of descriptive geometry, mathematics, strength of materials, mechanics, fabrication of materials, manufacturing methods, and machine and machine tool operations. This type of knowledge, whether it is applied to a product to be manufactured, a tool, or a structure, makes the difference an ordinary design and a good design, and is a prerequisite to further advancement. If this knowledge is not acquired directly by academic study, it must be acquired by the slower method of mistakes and eventual corrections. At this point in the trainee's career, his technical ability, his initiative, and his grasp of this method of engineering expression become increasingly apparent to the chief draftsman, the project engineers, and, in some cases, to the chief engineer. As he develops and acquires experience, the trainee becomes ready to assume the responsibilities of a senior layout man. It is at this point that the scheduled training program usually ends and the trainee is considered a professional draftsman.

The senior layout man has a wide opportunity to express originality and ability in design work, and the ultimate success of a manufactured product, a machine, or a structure is often determined on his drawing board. It is during this stage of his advancement that the draftsman becomes involved in engineering management within the drafting room. The degree of management varies, of course, with the individual, and is the result of a number of factors which have been established and evaluated during his employment.

The senior layout man may become a group leader and be responsible for the correctness and the application of the work of other men who are making detail drawings which form a part of an overall layout drawing. The senior layout man may become a checker, in which case he becomes responsible for the accuracy and adequacy of drawings to properly define the intended results. The senior layout man may become a junior and then a senior designer, in which case his talents may be used to collaborate with senior layout men and to work directly with the project engineers in starting new designs of products, or to create better and less costly methods and better and less costly designs of existing products.

The senior designer is the highest classification available to the draftsman, but instead of thinking of it as such, he should think of it as the ending of one phase and the beginning of another more promising phase of his career. It is his open door to opportunity and advancement to higher positions in engineering, manufacturing, inspection, sales or service, and eventually the management group of the company.

CONCLUSION

Draftsmen and designers are an essential part of our everyday existence. Every road, bridge, structure, machine, engine, household appliance, piece of furniture, piece of clothing, and practically everything else made for the use or comfort of man has at some time felt the influence of the draftsman. Moreover, as the universe and the natural laws that govern it become better understood, the man on the board becomes an ever more essential part of progress. Thus, any individual so engaged should view his personal efforts with pride in the realization that he is contributing his skill and services in a constructive manner for the benefit and advancement of society.

ACKNOWLEDGMENT

Acknowledgment is made to Mr. G. C. Porter, chief draftsman, and Mr. H. H. Dietrich, project engineer, for their valuable assistance in the preparation of this manuscript.

INSTRUCTIONAL GOALS OF ENGINEERING EDUCATION

by
Professor W. E. Street
Agricultural and Mechanical College of Texas

January 30, 1954

Professor D. H. Pletta, Secretary
ASEE Committee on Evaluation of
Engineering Education

Dear Professor Pletta:

In the meeting of the Policy Committee of the Drawing Division of ASEE, January 28, 1954, the central topic of discussion was that of Instructional Goals of engineering education listed at the bottom of page 8 of the Preliminary Report on Evaluation. Although we are in complete agreement with the goals as stated, it was felt that this section would be strengthened by pointing out that such training can be started in the freshman year. Therefore, we recommend the addition of the following sentences at the end of the first paragraph on page 9:

It is understood that the development of these characteristics must be a gradual process that should be started at the freshman level and continued throughout his career. Any situation that is new to the student may be used for training in this line as well as those research projects that deal with new fundamental material. To this end it is recommended that considerable attention be given to the application of these goals in the freshman year through the courses in drawing and engineering geometry (descriptive geometry) and in the sophomore year through the courses in physics and all other engineering courses.

Thank you for your consideration of this information.

Yours very truly,

W. E. Street, P. E., Chairman
Drawing Division ASEE Committee on
Evaluation of Engineering Education

COMMENTS ON THE PRELIMINARY REPORT OF THE ASEE COMMITTEE ON EVALUATION OF ENGINEERING EDUCATION

1. List Drawing under Curricula Areas and Content by independent heading and substitute the following for the fourth paragraph on page 12:

Engineering Drawing. Those in charge of courses in engineering drawing will need to continue to revise their objectives. In addition to teaching the recording and communication of ideas, drawing courses must be designed to develop whatever creative abilities a student may possess. Drawing teachers will need to recognize the concept that the engineering graduate will not be trained primarily to produce drawings, but that his principal job will be to supervise their production.

It becomes the responsibility of the Engineering Drawing Department to emphasize technical sketching and engineering charts and graphs, since these transmit ideas not only to draftsmen, but to supervisors and all others associated with engineering production. It may be necessary to de-emphasize skill, but the ability to understand this form of engineering communication must not be minimized because the profession regards drawing as an exact method of technical expression. It will be imperative to initiate in Engineering Geometry (Descriptive Geometry) methods of integrating graphic solutions of problems in Physics, Mathematics, and Mechanics. This gives the student complete freedom of expressing his original ideas in the solution of problems.

It is recommended that drawing teachers be given greater opportunity to participate in or supervise programs which rely on graphics for solution in engineering and scientific research or development.

Engineering Graphics has always been an integral part of the professional engineer's training and will continue to be so; however, the contents of present courses must be continually revised to meet the demands which the profession will impose in the future.

2. List Drawing under the requirement for the professional General Curriculum.

The above has been approved by the Policy Committee, Executive Committee, and Officers of the Drawing Division of ASEE at the Midwinter Meeting of the Drawing Division of ASEE at the University of Pennsylvania, January 28-30, 1954.

Dean Jasper Gerardi, University of Detroit
Prof. F. A. Heacock, Princeton University
Prof. John T. Rule, Massachusetts Institute of Technology
Prof. W. E. Street, Chairman, Texas A & M College

EDITOR'S CORNER

With this issue we finish another academic year. A year in which most of us have given much thought to our courses in Engineering Graphics. As your editor, I have attempted to present varied viewpoints with the hope that each of you may be helped by the thinking of others.

During this busy year, time has not been available to write each one of you who have presented an article for publication. If your article has appeared on our pages, you can know that many of us have appreciated your efforts. If your paper has not as yet been printed, it will probably be used at a later date. In any case, please accept your editor's thanks.

Two Euclidian solutions to John Rule's Fido problem are presented in this issue. Our thanks to all of you who sent in approximate methods. Due to a shortage of space these could not be published.

The following schools have 100% subscription records for 1953-54.

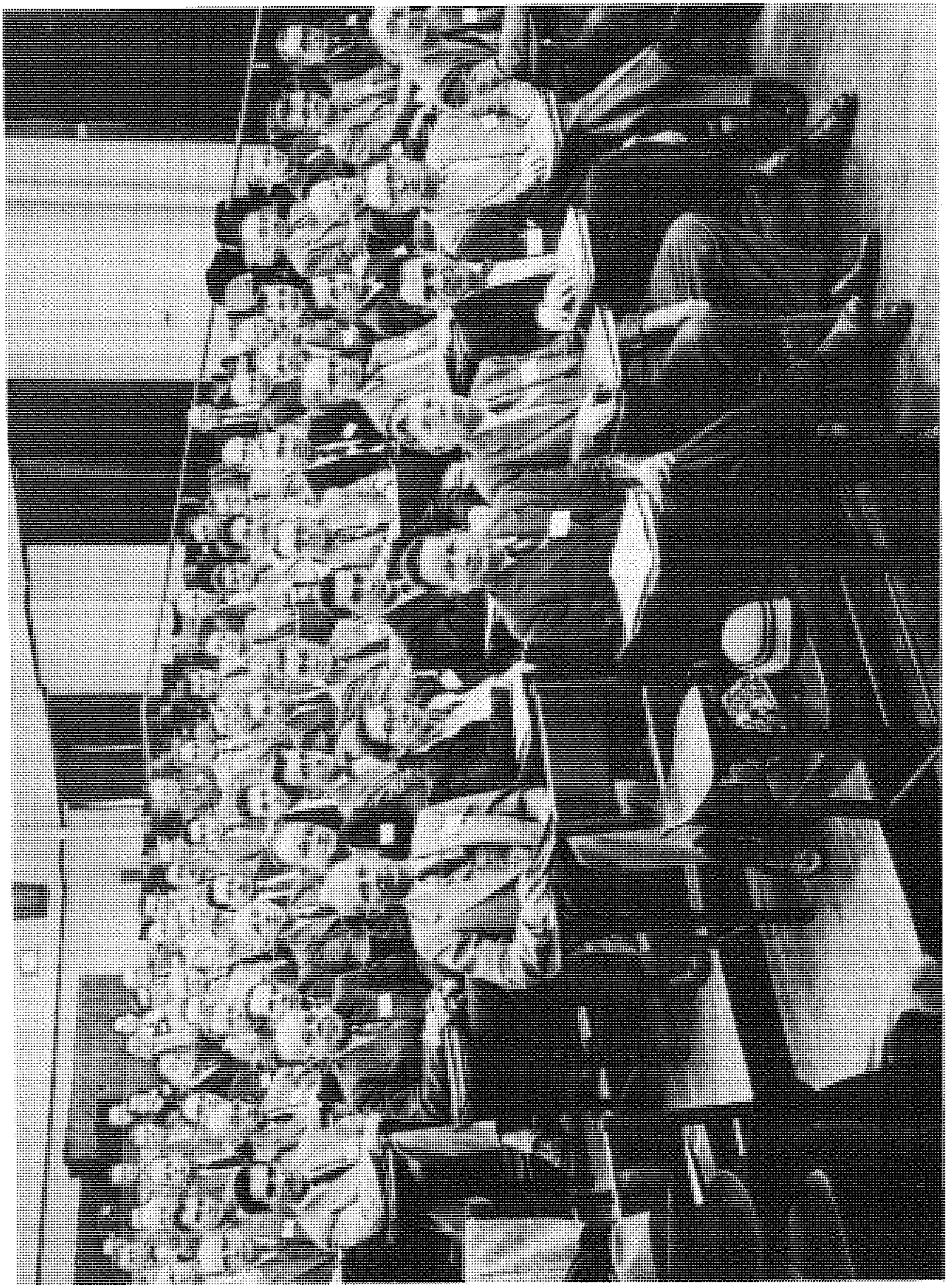
Ohio State University

Clemson Agricultural College

Iowa State College

University of Maine

New York University



MIDWINTER MEETING
University of Pennsylvania
January 28-30, 1954

A REAPPRAISAL OF ENGINEERING DRAWING

by
Professor R.P. Hoelscher
University of Illinois

The recently issued preliminary report (October 10, 1953) of the ASEE Committee on "Evaluation of Engineering Education," supplies both an incentive and a background for a restudy of our work in Engineering Drawing. While the preliminary report will no doubt be revised one or more times before it is finally accepted by ASEE, I believe the position taken in this report on Engineering Drawing is not likely to be modified.

As a background for our consideration, I would like to quote from this Report, first the goal for Engineering Education as a whole, and second the specific reference to Graphical Representation.

Since each course in any curriculum must contribute something to the final or total objective we shall consider that item first. It is stated as follows: "The technical goal of engineering education is preparation for performance of the functions of analysis and design or of the functions of construction, production or operation with full knowledge of analysis and design of the structure, machine or process involved. The broad objective of engineering education should also include the development of leadership and inculcation of a deep sense of professional ethics and the general education of the individual."

Few of us will take exception to this statement of the technical goal of engineering education for it is difficult to conceive how the functions of analysis and design or the function of construction or production could be fulfilled without an adequate knowledge of Graphical Representation.

Two specific references are made in regard to Drawing as follows:

"Graphical representation is both a form of communication and a tool for analysis. Its professional usefulness may be evaluated in terms of its success in these directions. Its value as a skill alone does not justify its inclusion in a curriculum. The ability to convey ideas by drawing should be measured at an appropriate time and where deficient should be developed so that its use is evident in reports presented in advanced courses. Another ability to be developed in this study is spatial visualization. Since most creative engineering work is initiated by the process of illustrating ideas by sketches, it is believed that an experience in the use of technical sketching that may be obtained in drawing offers the opportunity for initiating the creative process."

The second reference states: "Drawing should be taught in such a manner as to develop creativity, spatial visualization and the ability to convey ideas, especially by freehand sketching. Its value as a skill alone does not justify its inclusion in a curriculum."

In these quotations the objectives of our work in Graphical Representation, are laid out in broad outline. With these general statements we take little exception but it is quite likely that there will be considerable difference of opinion as to their specific and detailed meaning. One thing is quite clear, however, since it is mentioned twice in the quotations above, namely, that emphasis can no longer be placed on manual skills in the execution of drawings. The committee which prepared the report seem to be agreed upon this and I would be quite willing to go along. We trust, however, that those who get our student later will not expect them to do good lettering and to execute drawings with skill and finesse.

I have a strong suspicion that one of the reasons behind the pressure for reduction of time in drawing has been an over emphasis on skills in instrumental drawing. I quite agree with the committee that the time for this has passed. Whatever skills we develop must be a by-product of our teaching rather than a major objective.

Let us then consider the other objectives which have been named to see if we can expand them into more specific objectives. The objectives mentioned are - -

1. Drawing must be a means of communication.
2. It must be a tool for analysis.
3. It must develop spatial visualization.
4. It should develop creativity.
5. It should develop skill in freehand sketching.

These are the goals mentioned in the report. You may or may not consider them adequate. Certainly our courses in Engineering Drawing provide a wider educational background than that indicated in these five items.

I am convinced that some of these items are of sufficient value to warrant mention in an attempted appraisal of engineering drawing. The following items should certainly be included.

(a) Development of methods and habits of procedure which are essential to any engineer or executive namely, the accurate, complete and orderly presentation of any material entering into consideration in an engineering project. These are not inborn characteristics. They must be learned and become habitual.

(b) Development of a technical or engineering vocabulary. This is probably one of those things which some of our engineering educators maintain would be picked up by the student as he goes along through life. Actually people do not build up their vocabularies unless there is a reason for doing so. That motive is supplied in Engineering Drawing and the technical terms occur naturally in this field. They do not occur in mathematics, rhetoric, chemistry or physics except the concepts or terms peculiar to these fields.

(c) A rudimentary knowledge of what can and what cannot be economically done in the shop, shop courses have been largely eliminated so that the drawing course is the only place left where the student may acquire this information. This is the logical place to teach it since the drawing determines what the shop operations must be. If the operations are impossible or unnecessarily expensive the drawing must be done over.

Among the leaders in engineering education there are those who subscribe to the theory that a young engineer will pick up such information as he goes along together with a great deal more. I cannot accept this theory for the average freshman has picked up very little in his first 18 years of life that is useful in engineering and in fact he has retained very little of the material such as geometry to which he was directly exposed in high school.

Forgetting now these details, if we accept these general objectives of the committee, our difficulties begin in interpreting them. We shall probably not agree among ourselves and probably the members of the committee would likewise not be in perfect agreement either among themselves or with us. Let us examine them one by one even though we cannot teach them on that basis.

1. Drawing as a Means of Communication. We used to call drawing the "language of the engineering." This phrase is now a worn out "cliche" and so we use the longer and more popular word communication.

The nub of the matter is, how good must this means of communication be and how well should the young engineer be able to use it. If we are willing to leave the engineers ability to communicate ideas in the stage of the Indian Smoke signal or the African drum beat then certainly a very short course is required.

Communication among engineers and between engineers and skilled workmen is not that simple. It involves not only an accurate description of the shape of an object but its size, and relationship to other objects as well. Nor is that enough, for an object must be made of a suitable material which must be treated and finished in a very specific way. All of these things are shown on a drawing. It is true that the draftsman does not decide upon all of these things but the engineer must do so and he must know how to have the draftsman express them on a drawing in ways that can be understood by others. We are training engineers, not draftsmen.

Drawings for buildings, bridges, dams and the like have always been the legal basis for contracts. Today, drawings of machine parts are more and more frequently being used as a legal basis for contracts.

As mentioned before, we are training engineers and not draftsmen. We are concerned not primarily with skills and beautiful line work but rather with knowledge and understanding. The engineer who approves a drawing, not the draftsman who makes it, must know that the drawing calls for what he wants, and is made as he wants it.

The idea of communication may be carried a bit farther. We have enjoyed talking about drawing as the universal language of the engineer which, except for notes, can be understood the world over. But unfortunately this isn't true.

In 1940 when Britain was desperately pressed for aircraft engines she turned to American Industry for help. She sent one of her Rolls-Royce Merlin engines to the Packard motor car company along with a ton and a half of blueprints.

This was an exacting engineering job. Before a wheel could turn some 300 engineers and draftsmen had to convert the British drawings into American drawings. Some other items, beside drawings which were understandable in American shop, were involved but almost two years were lost in the production of this engine because of the necessity of making the drawings all over.

Obviously drawing is a very simple means of communication, to be picked up as one goes along, yet strangely enough we are now in our sixth year of working on an American Drafting Standard and we haven't finished it yet. One section on Dimensioning and Notes stands in the way of agreement among ourselves and with the British and Canadians.

Our job is to teach this art of communication, as efficiently as possible, in the least amount of time. We must decide therefore, what to include and how much time we must spend on each part of our work.

What then can be included in a beginning two or three credit hour course. Few of us now have more than that amount of time available. Beyond accurate and adequate shape, size description and descriptive geometry, shall we add pictorial forms of representation, charts and diagrams, elaborate geometrical constructions, rectification of curves and determination of empirical equations, nomography and graphical calculus as well as a few specialized fields of drawing. To me this does not sound reasonable, but it is being done in some areas.

To me the inclusion of such a wide variety of items in a beginning course is definitely a retrogression. I believe this has been caused by the pressure to eliminate drawing from the curriculum and represents an effort on the part of drawing teachers, to show that drawing or graphics as they like to call it, does have mental concepts as well as manual skills. To resort to this procedure is a frank admission that we have had far too much time for teaching engineering drawing.

It should be noted that the Committee Report referred to, speaks of Graphical Representation and not Graphics. Our first and most important job is to give the student a means of accurate communication, for the purposes of design, construction or operation. This cannot be done in less time than we now have.

2. Tool for Analysis. Analysis usually means solving a problem of some kind. In Graphics we usually think of descriptive geometry as a means for problem solving. It is an excellent instrument for that purpose, particularly so if problems are lifted from the routine theoretical concept to a practical situation which does require the analysis or breakdown of the problem into its mathematical aspects.

We should not, however, rely solely on descriptive geometry to develop the problem solving ability. More of it should be done in our beginning drawing courses. It may be difficult to do this but I believe it is far better for the student, that we exert ourselves in this direction, than to insert extraneous graphical concepts of which he can get somewhat less than a smattering.

3. Development of Spatial Visualization. This is supposed to be pre-eminently the role of descriptive geometry. I would not devy its value in this field but I believe we sometimes reverse the process. By and large we do not visualize a problem in descriptive geometry and then solve it. Rather the reverse, we solve the problem by an analytical reasoning process, make the drawing and then it is possible to get a visual concept.

For young men who have had no previous experience with drawing (and that means 60 per cent of our students in the mid-west) the interpretation of two and three view drawings is not easy. There are quite a few who have difficulty in getting an accurate three dimensional concept even from a pictorial drawing. I know of no method which will develop their ability except increased experience and this takes time.

4. Development of Creativity. This is another way of saying that we must develop originality, ingenuity and imagination, for all of these qualities are required in creative design. Those of you who attended the Dartmouth meeting will recall that this was perhaps the major theme of Dean Hollister's talk. There is some questions in my mind as to whether this quality can be developed in all students. I believe the engineer's creativity must have more down to earth qualities than the screw-ball creations of modern art.

We can, however, develop some qualities or originality by requiring our students to redesign some objects instead of simply reproducing them from pictorial to multiview form or the reverse. This is perhaps one of our weak spots in the teaching of engineering drawing. I believe there is room to improve our work in this respect.

5. Freehand Drawing. Facility in the use of freehand drawing as a means of conveying ideas has been emphasized by the committee. The trend in industry seems to reinforce this point since it is expensive to use engineering graduates on the drawing board when their other skills can be used to greater advantage. Whether we like it or not we must provide more training in freehand sketching. Here again the actual line work is not nearly so important as the development of a good sense of proportion. The student must be able to draw lines parallel to each other, perpendicular to each other, and to draw angles such as 30°, 45°, etc., at approximately their correct value. Circles and ellipses need not have corners on them even if made free-hand.

Those of you who have examined the text "Simplified Drafting" by Rau and Healy can readily recognize that a great deal of the simplification recommended in this text consists of free-hand drafting and the authors present conclusive evidence that their recommendations have saved their companies money.

There is another aspect of the industrial drafting situation which makes it almost mandatory that our students acquire reasonable proficiency in free-hand sketching and that is the trend toward unionization of draftsmen. Union contracts specify who shall be classified as a draftsman and that frequently prevents the engineer from using T-square, triangles, etc., in making his drawings. If he wishes to stay out of the draftsman category he must limit himself to free-hand sketches.

This brings me to a consideration of the topic announced as my theme namely specialized courses in Drawing beyond the freshman level. I am definitely advocating such courses. Some to be required courses, others elective.

(A) Required courses. My reasons for believing that required courses in the sophomore year are highly desirable may be presented rather briefly.

1. The time now allotted to the customary two beginning courses given in the freshman year is definitely too short to develop a sound ability to read drawings, let alone make them. I am convinced that a part of the students difficulty in advanced courses is his inability to read and correctly interpret the drawings and illustrations in his text books, laboratory manuals and quizzes.

A poorly made free-hand diagram in mechanics, for example, can lead to errors of analysis. Failure to understand a sketch in a text book makes study quite difficult and at times useless.

2. The gap which now exists between freshman drawing courses, and the Junior and Senior design courses, where drawing must be used as a means of communication or to convey ideas, is too long for effective carry-over.

The whole idea of carry-over of material and methods, learned in one course, to useful application in a later one has not been shown to be educationally very effective. When the application is delayed for a full year or more, little carry-over can be expected.

It is therefore desirable from the viewpoint of adequate communication alone that this gap be bridged by some drawing courses of a professional level.

3. Professional Concepts. Since our short beginning courses provide time for the representation of only the simplest objects usually machine parts, they cannot give to the civil, mechanical, electrical or aeronautical engineer any concept of the drawings and methods used in their professional fields.

For the civil engineer the problems he faces in map, structural and building construction drawing simply cannot be covered in a beginning course. A sophomore course covering this material would make his work in surveying, structural design and building construction much more effective. Time, which must now be used in design and surveying courses to teach the methods of representation in these fields could be more effectively used to teach the real subject matter and principles of these courses.

The same thing can be said for other fields of engineering. For the mechanical engineer the proper selection and specification of allowances, and tolerances of size and location tolerances, cannot be taught in a beginning course. This is not a simple matter. Our subcommittee on "Dimensioning and Notes" of A.S.A. Y-14, has been at work for about 2 years and they have not yet come up with a satisfactory draft. The men on this committee are all engineers in positions of responsibility. If this problem were an easy one this report would have been finished long since.

4. With elementary drawing and descriptive geometry as a background, problems of a practical engineering character can be assigned. Such problems can have more than one solution and will begin to introduce the student to the engineering method of attack.

(B) Elective Courses. There are other areas in the field of graphics in which quite a number of engineering students should have a legitimate interest. Such courses could well be offered as electives where there is a large enough total enrollment to warrant such an offering. A few of these areas are as follows:

1. Production Illustration. A course of this kind can be made of high calibre if theoretical training in axonometric and one, two and three point perspective is offered together with a reasonable amount of training in the art of rendering drawings by various techniques. Problems in perspective can test and develop the students ability to think in three dimensional space. Once the theoretical concepts are understood, free-hand work can be used effectively. A prerequisite of descriptive geometry must be set up as a minimum requirement.

2. Graphical Computations. Many years ago it was common to make the analysis of stresses in trusses by graphical methods. The older men, present here, probably had a course called graphic statics. This has now been largely superseded by algebraic methods of analysis. I am therefore not recommending a return to this procedure, though vector diagrams which form the basis of graphic statics and other fields of analysis are still useful. The following material could well be coordinated as an advanced course in graphics.

(a) Rectification of curves and determination of empirical equations. It is true that this is touched upon in analytical geometry but a wider application gives the student a more thorough command of the subject. It has many practical applications.

(h) Nomography. This can be based upon plane geometry or upon determinants according to the mathematical ability of the students. This subject is widely applied in engineering practice as can be seen from the fact that Professor Douglas P. Adams has made a bibliography of over 1700 nomographs published between the years of 1923 to 1950. Without doubt hundreds more were made without being published.

(c) Graphical Calculus. If this material is offered either concurrently or after the regular calculus course it will enhance the understanding of the student in both areas.

There is an ample amount of material in these three areas for a two or three hour course at the Junior level.

We believe that the offering of such a course will enhance the standing of any graphics department and bring the staff out of the rut into which teachers of drawing too easily sink. Where enrollments are large enough there will be no difficulty in securing adequate registration in such a course.

There are other areas which I am sure some of you could suggest but I shall limit myself at this point with the observation that whenever Graphics courses are offered at the Junior or Senior level they should be commensurate in difficulty with the Junior and Senior design courses in the regular curricula. Only in this way can we retain the respect of degree granting departments.

I am convinced that we can enhance the standing of our Drawing Departments and command the respect of our colleagues in degree granting departments if we present our course material with a view to attaining the objectives set forth by the Committee on Evaluation of Engineering Education. Likewise the offering of advanced work in Graphics will be approved, and registrations secured, when we convince our colleagues of its value.

BEAUTY AND THE CENTER OF GRAVITY

by

Fridtjof Paulsen

San Mateo Junior College

The elements which underlie and contribute to the esthetic quality of a form are many and varied and often subtle. One of these is the sense of the center of gravity, a most subtle feature of these forms which are apt to come before an individual for his contemplation, particularly in the field of art. While an observer may not realize that the center of gravity plays a part in the response to the beauty of a form, nevertheless his sense of its presence and even its location does much to sort out those forms which he terms beautiful. Center of gravity is an efficient device for the mathematician and the engineer; to the layman it is apparent to his sense to an unusual degree; and the perception of it guides the artist constantly.

One of the problems encountered in the study of forms is the mathematical relation which exists between the center of gravity and the form itself. Studies of form have resulted in formulas for particular shapes; for instance, Fechner determined which proportions of a rectangle's sides is most pleasing. Work by Hambidge on dynamic symmetry enlarged the field of study of rectangular shapes and contributed to the phase of art involving rhythm. In those cases, however, the center of gravity does not play a part though they do give precedence for a mathematical approach to an understanding of the esthetics. The author made a study of shapes other than rectangles, particularly those used for simple vases wherein the base was narrower than higher portions of the form. It became quite evident that a particular relation between the center of gravity and the outline existed to distinguish those shapes which were judged to be most pleasing.

Let us examine some of the examples of rules in the field of art in which mathematics is used and then follow through with the problem of centroids. The first of these is that of the "golden section". This is the rectangle whose ratio of width to length has come to be accepted as the ratio which gives the most pleasing proportion. Mathematically stated, the width is to the length as the length is to the sum of the width and the length, or

$w:l :: l:w+l$ where w is the width and l is the length

The solution of the resulting quadratic shows w equal to .618 of l. In Figure 1 the geometry of the relation is shown, based on a square. This solution makes use of the mean proportional. The ratio of width to length of the "golden section" shown still holds, although the notation for the sides has been changed from the proportionality statement above. It is interesting to note that the assistance of the mathematician in esthetics has not been rejected in this case.

Another example of the application of mathematical principles in art can develop from the analysis of balance. Basically, the balance which can be illustrated by a seesaw illustrates the fact. The mechanics of balanced masses is represented with the heavier of two masses nearer the fulcrum, as in Figure 2. This is a very simple case serving to show how readily the center of total mass can be readily sensed at the fulcrum. This fulcrum is the point where the artist perceives his "center of interest." To the artist this simple illustration is hardly intriguing enough to be called art, but the principle does enable him to organize his work.

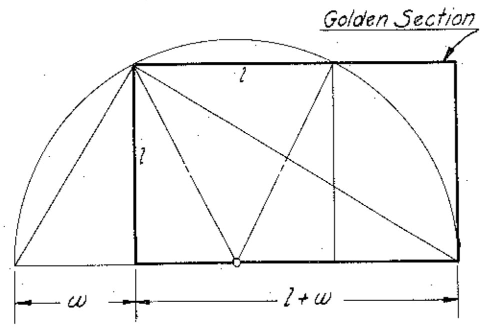


FIGURE 1. Geometry of Golden Section

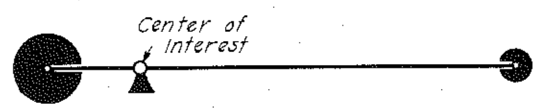


FIGURE 2. Illustration Showing Center of Interest in the Balancing of Areas

The sculptor, too, must preserve balance in his work. In this case mechanical balance is involved. The mathematical solution for the location of the center of mass in the three-dimensional form becomes very involved in most cases. However, by limiting the objects to vases and those objects which are classed as forms of revolution, the problem can be dealt with in a simplified relation not much more complicated than was found in the case of the "golden section" or the problem of seesaw balance.

Taking the simplest case, we can use the inverted frustum of a cone. This shape is found in drinking glasses, flower vases, and pans for various uses. The proportions which are found to be most pleasing to the eye are those which produce a feeling of positive balance together with pleasing proportions. The observer's sense of the location of the center of gravity or centroid comes into play. The author has found a basic rule hy which the most pleasing proportions might be arrived at, and has given it the name FORM-TANGENT RULE. This rule brings together the center of gravity and the outline as interacting elements of design. Figure 3 illustrates the application of the FORM-TANGENT RULE to the trapezoidal section.

Point "o" is the location of the centroid of the figure. When the sides "ac" and "bd" are parallel to the sides "od" and "oc" respectively, the FORM-TANGENT RULE has been observed. Figure 4 shows examples of figures which do not meet the rule.

The FORM-TANGENT RULE applies to other figures than trapezoids. By cutting off the lower portion of a circle to form a base, the tangent lines "ac" and "bd" follow the same rule, as in Figure 5. Such circular outline forms can be found in moon-gates and onion-top towers. In Figure 6 the tangent line from the base of the form used in a wine glass is tangent at a point along the outline near the top of the figure. As long as the tangent lines from the ends of the base of the figure are parallel to the sides of the triangle formed by the base line and the center of gravity of the figure, the FORM-TANGENT RULE applies. The incandescent lamp is another example of a well-proportioned form with a reverse curve outline.

The direct mathematical solution is difficult, but the use of cut-outs can obviate this difficulty. Figure 7 illustrates the method used with a circle as the basic figure. Cut off from a circular piece of cardboard a segment of the circle. This step is shown in (a). Then hang a weighted string from a pin stuck through the cardboard, allowing the cut-out and the string to be freely suspended from the axis of the pin. The pin can be pushed through the cut-out near the end of the chord of the figure. See (b). Draw a line on the cut-out to match the position of the string. Push the pin through another point on the cut-out and repeat the procedure as shown in (c). The intersection of the two lines on the cut-out gives the location of the center of gravity. If the tangents to the circle at points "c" and "d" are parallel tc the sides of the triangle formed by points "o", "c", and "d", the FORM-TANGENT RULE has been met. If parallelism does not occur, line cd should be brought closer to the center of the circle by cutting another piece from the cut-out, parallel to the first cut and the process repeated. Several trials may need to be made.

The FORM-TANGENT RULE holds more than academic interest. The industrial designer may have occasion to produce articles of the nature of those shown in this article, and when he does, he may be guided by the rule to a direct solution. There are machines such as gear reducers whose design indicates that the base should be narrower than upper portions, and when the engineer can accept the esthetic values in a design in these cases, he may find that a saving of space and material will accompany the design. It is not necessary to stop with vases and glassware.

APPENDIX

A direct mathematical solution has advantages over the cut-out method shown in the body of this article. The author adds typical solutions for the trapezoidal form.

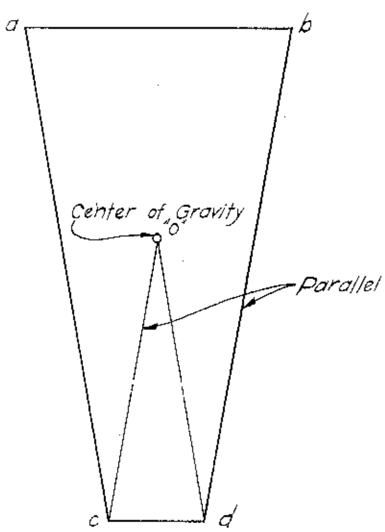


FIGURE 3 - FORM-TANGENT RULE FOR TRAPEZOID

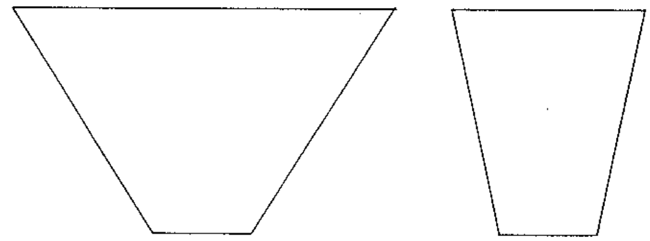


FIGURE 4 - TRAPEZOIDS WHICH DO NOT FIT FORM-TANGENT RULE

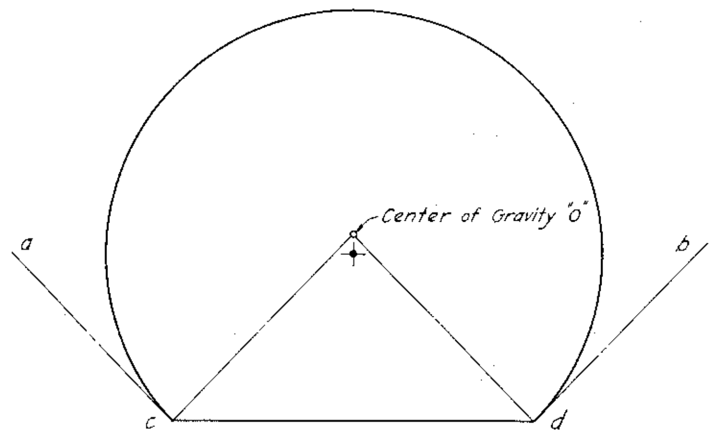


FIGURE 5 - FORM-TANGENT RULE APPLIED TO THE CIRCLE.

Solution A Figure 8

Volume of revolution of area mnpq = volume of cylinder pqq'p' - volume of cones qq'n and pp'm

$$= 2c\pi h^2 - 2[\tfrac{1}{3}\pi h^2(c-1)] \qquad (1)$$

Volume of revolution of area mnpq = $2\pi\bar{x}$ times area pqnm

$$\text{or, } \bar{x} = \frac{\text{Vol.}}{2\pi(\frac{2c+2}{2})h} = \frac{\text{Vol.}}{2\pi(c+1)h} \qquad (2)$$

Simplifying and substituting (1) in (2):

$$\bar{x} = \frac{2\pi h^2(3c-c+1)}{2\pi 3(c+1)h}$$

$$= \frac{2\pi h(3c-c+1)}{2\pi 3(c+1)} \qquad (3)$$

From (3) $\frac{\bar{x}}{h} = \frac{2c+1}{3c+3}$ (4)

But $\frac{h}{c-1} = \frac{\bar{x}}{1}$ by the condition imposed by the FORM - TANGENT RULE

from which $h = \bar{x}(c-1)$ (5)

Substituting (5) in (4)

$$\frac{\bar{x}}{\bar{x}(c-1)} = \frac{2c+1}{3c+3}$$

from which the following quadratic is gotten:

$c^2-2c - 2 = 0$

and $c = 2.732$

The slope $\frac{h}{c-1}$ then becomes $\frac{h}{1.732}$ (6)

Assuming h = 1 as a particular case, the slope of the trapezoid's sides equals

$\frac{1}{1.732}$ or .5797

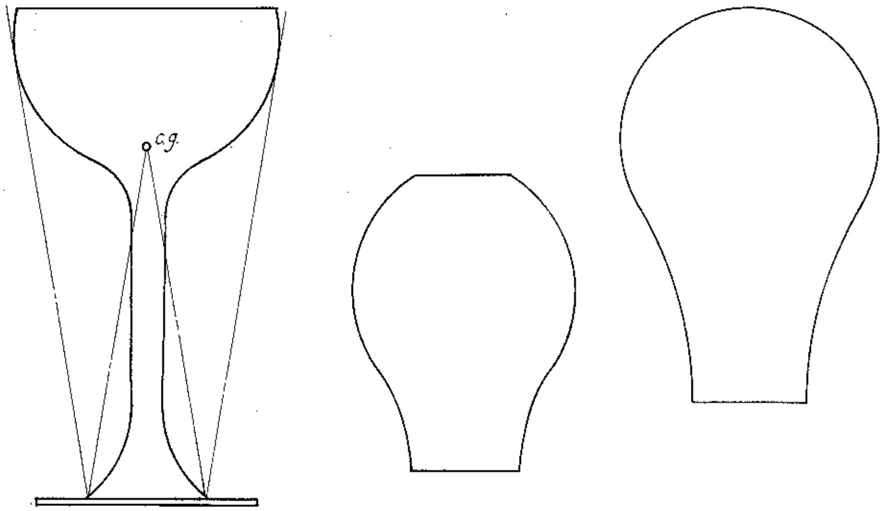


FIGURE 6 FORMS WHICH MEET FORM-TANGENT RULE

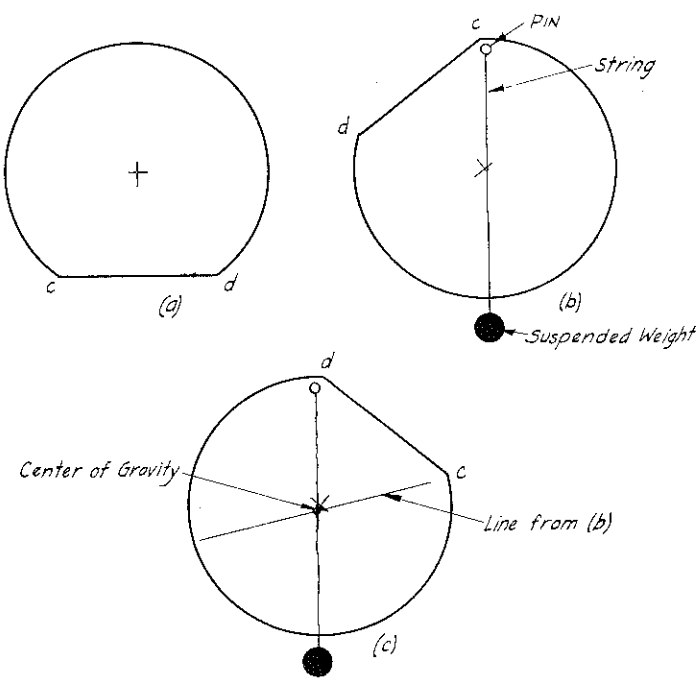


FIGURE 7. USE OF CUT-OUT TO FIND CENTER OF GRAVITY

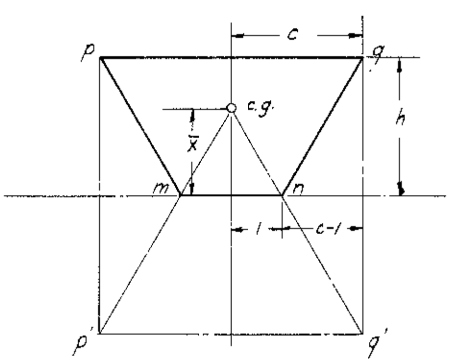


FIGURE 8. GEOMETRY FOR APPLICATION OF FORM-TANGENT RULE TO TRAPEZOID.

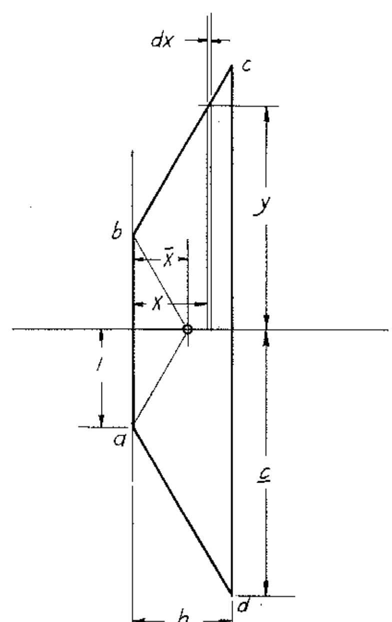


FIGURE 9. ILLUSTRATION FOR SOLUTION TO FORM-TANGENT RULE FOR TRAPEZOID

<u>Second Solution</u>

A more direct approach follows. Refer to Figure 9.

Let the slope of ao = the slope of bc

$$\bar{x} = \frac{\int_0^h x\,dA}{\int_0^h dA} = \frac{\int_0^h xy\,dx}{\int_0^h y\,dx} \quad (1)$$

but $y = l + xy'$

$$\therefore\ \bar{x} = \frac{\int_0^h x(l+xy')\,dx}{\int_0^h (l+xy')\,dx}$$

$$= \frac{\int_0^h (x\,dx+x^2y'\,dx)}{\int_0^h (dx+xy'\,dx)} \quad (2)$$

Let $y' = k$, and since $\frac{\bar{x}}{l} = \frac{1}{y}$

$$\bar{x} = \frac{1}{y'} = \frac{1}{k} \quad (3)$$

Solving (2) after inserting (3) in (2):

$$\frac{1}{k} = \left[\frac{\frac{x^2}{2} + k\frac{x^3}{3}}{x + k\frac{x^2}{2}}\right]_0^h$$

$$= \frac{3h + 2kh^2}{6 + 3kh} \qquad (4)$$

from which

$$6 + 3kh - 3hk - 2k^2h^2 = 0 \qquad (5)$$

Simplifying and solving (5)

$$2k^2h^2 = 6$$

$$k = \frac{\sqrt{3}}{h}$$

Assuming $h = 1$, then $k = \sqrt{3}$

But the slope of the sides with respect to the base is $\frac{\bar{x}}{1} = \frac{1}{k}$ from (3).

$$\therefore \bar{x} = \frac{1}{\sqrt{3}} = .5797$$

The foregoing solutions hold for only one condition, but all heights will give the same ratio of top base to bottom base.

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ANNUAL MEETING

June 14-18, 1954

University of Illinois **Urbana, Illinois**

Professor Frank M. Warner

PERSONALITY SKETCH
of
PROFESSOR F. M. WARNER

by

Professor E. R. Wilcox

University of Washington

Frank M. Warner needs no introduction to the "old timers" in the Engineering Drawing fraternity nor to a considerable number of the not so old timers. His ever popular text "Applied Descriptive Geometry," now in its fourth edition, has served to acquaint a very sizable group of teachers throughout the country with his simple and direct way of thinking and also of his sincere interest in aiding in the development of like traits in the young engineering student.

But there are several facts in connection with his life experiences and some aspects of his character and disposition which many of his friends might like to know more about. On the occasion of his retirement this June from active teaching duties after 47 years of teaching, interspersed with business and professional experience, it seems appropriate to sketch briefly some of the highlights of his career.

Professor Warner was born on April 24, 1884 at Scranton, Iowa. He married Cornelia E. Stanley in Spokane, Washington on December 24, 1912. They have two daughters, Mrs. J. G. Patrick of Portland, Oregon, and Mrs. R. L. Hamack of Edmonds, Washington, and six grandchildren.

Following his high school graduation at Morrison, Illinois, he attended Oberlin College, Ohio for one year, then after four years at the University of Wisconsin he graduated in 1907 with a B.S. in Mechanical Engineering. Some advanced work later at the University of Washington completed his formal education.

Professor Warner began his teaching career the same year that he graduated from college, thus early manifesting the major interest of his professional life, working with young folks in developing skill and interest in the use of the graphic arts in engineering. This first year of apprenticeship as an instructor in drawing at the University of Wisconsin was served under Adam Miller, with whom some of the "old timers" may remember talking over the former days, during the Gainsville convention last June.

Following an urge to go West and grow up with the country, Prof. Warner spent the next two years as an instructor and Assistant Professor of Drawing and Mechanical Engineering at the Washington State College at Pullman. From here he went to Spokane, Washington to engage in his own business of drafting and patent work coupled with a blueprint shop. It was here that through his church and musical interests he met and later married Cornelia Stanley. These two interests together with a very devoted family life have occupied most of his leisure time since then. He is always ready to lead a group in singing and his continuous and faithful church work led to his election as a life elder in the University Presbyterian Church of Seattle.

In 1913 he gave up his business in Spokane to accept an assistant professorship in Engineering Drawing at the University of Washington in Seattle, where he remained for four years, developing his ability as an outstanding teacher in his field. Lured by the more lucrative rewards of industry at a time when the demands of a growing family were heavy, he left teaching to go with the Alberni-Pacific Lumber Company which was operating a large saw mill at Port Alberni, Vancouver Island, B.C. Here he rubbed elbows with Sikhs, salesmen and sea captains while supervising the harvesting, manufacturing, and shipping of the products of the virgin fir forests of this island. When he left there in 1925, he was assistant manager of the firm.

Fortunately for the Engineering College at the University of Washington, there was an opening at that time for a man to take charge of the Engineering Drawing work in the new department of General Engineering which had been given the supervision of all first year students in the college. Prof. Warner was offered the position, and he gladly returned to his first love with such ardency that according to carefully conducted classroom polls, he has consistently maintained his standing among the top ten per cent of all University of Washington teachers. His colleagues in the college are in full agreement with the student opinion.

In order to keep in touch with the changing needs and demands of industry in his field, Prof. Warner worked during the summers with various companies in such fields as structural steel, manufactured gas, navy contractors, and the airplane business, also spending one summer in developing a course in applied descriptive geometry for the Curtis-Wright Technical Institute at Glendale, California.

Professor Warner is best known of course to readers of this Journal for his work with the Drawing Division of the ASEE where he has served on various committees such as Descriptive Geometry Standards, Visual Aids, Tests, and as a member of the Sub-Committee on Drawing of the American Standards Committee. He is the author of several articles in Engineering Drawing Journal and Journal of Engineering Education and joint author with Prof. C. E. Douglass of a Problems Book to accompany his text. He is a past president of the Pacific Northwest Section of ASEE and a member of Tau Beta Pi and Sigma Xi.

Outside his professional field he has served on many college and university committees. He is past president of the University Lions Club, a member of the Seattle Municipal League and the American Bible Society. Whatever his job or assignment, he is always ready to carry more than his share of the load, always cheerful and looking for his little joke which is always kindly and appreciated by everybody.

Professor Warner's many friends and colleagues are going to miss greatly his active participation in the affairs of the Drawing Division, but they can continue to expect his active interest in their doings. As he has more leisure to indulge in his hobbies, one of which is traveling with his color camera, he may stop by to pay some personal visits which he has had to defer until now.

From the multitude of students who have passed under Prof. Warner's supervision, many of whom he has counseled on personal as well as scholastic matters, come letters of appreciation, not only from across this country but from various places abroad, telling of their experiences and expressing their appreciation of his work. They are apt to remember some friendly comment, usually with an unusual twist, pointing out their lack of logic, foolish mistake, etc., that made a lasting impression, or it may have been some insight into the approach to a tough problem that has helped them in the solution of a later "stumper."

All of us, his colleagues who have worked with him over all or part of the past 29 years at the University of Washington, his former students, and his many friends and associates in the Engineering Drawing field, appreciate the privilege of his friendship and the influence of his irresistible enthusiasm and wish him satisfaction and happiness in the continuing opportunities for services which still await him.

A LETTER FROM THE DIVISION CHAIRMAN

Dear Colleagues:

The work in Engineering Drawing has undergone considerable change during the past twenty-five years. This change reflects itself in course titles, course content, subject material and problems.

In the schools represented in the Division of Engineering Drawing of ASEE, the emphasis in the field of graphics is upon analytical reasoning and problem solving as it relates to engineering and in the development of technical scales.

Our June meeting, as you will see from the program outlined below emphasizes this new trend. I am sure you want to be counted among those who so well expressed their feelings following the Mid-Winter Meeting in Philadelphia. I quote,

"I want to tell you how much I enjoyed the meeting of the Drawing Division which was held last week at the University of Pennsylvania."

A young instructor - "If all drawing meetings are as good as this, I'll never miss one."

"The best drawing meeting I ever attended."

"The inspirations received have given me a new urge to get back in the classroom and go to work."

"The most enjoyable meeting I ever attended."

"Everything was as near perfect as it could be."

"Everything was well organized and I did not hear a single complaint regarding the meetings or facilities provided."

I trust I might have the honor of meeting you again at the June meeting.

Sincerely yours,

Ralph T. Northrup
Chairman, ASEE
Drawing Division

PROGRAM
ANNUAL MEETING
of the
ENGINEERING DRAWING DIVISION OF THE ASEE

University of Illinois, Urbana, Illinois
June 14-18, 1954

Monday, June 14:

2:00 p.m. A Re-evaluation of Engineering Graphics.
Chairman: Professor Theodore T. Aakhus, University of Nebraska, Vice-Chairman Drawing Division ASEE.

Technical Papers --

(a) "Teaching Engineering Graphics Effectively for Today and Tomorrow," Professor Frank A. Heacock, Princeton University.
(b) "A Positive Program for Engineering Drawing," R. S. Sherwood, Worthington Corporation.
(c) "The Fundamentals, 'What Are They?'," Professor Kevin B. O'Callahan, University of Buffalo.

6:00 p.m. Executive Committee Meeting, Division of Engineering Drawing, "The Wings," Rantoul, Illinois.
Chairman: Professor Ralph T. Northrup, Chairman Division of Engineering Drawing, Wayne University.

Tuesday, June 15:

2:00 p.m. Graphics: An Important Element in Aiding Research and Explaining Results.
Chairman: Professor Ralph T. Northrup, Chairman Division of Engineering Drawing, Wayne University.

Technical Papers --

(a) "Graphics in an Expanding Scientific Age," Professor Albert S. Levens, University of California, Berkeley.
(b) "Analytic Graphics and Engineering Problem Solving," Professor Raymond A. Kliphardt, Northwestern University.
(c) "Modern Methods for Reproducing Drawings Used in Research Reports," Professor Harold P. Skamser, Michigan State College.

6:30 p.m. Twenty-fifth Anniversary Dinner, The Past and the Future.
Chairman: Professor Ralph T. Northrup, Chairman Division of Engineering Drawing, Wayne University.

(a) "The Past and the Future," Professor Frederic G. Higbee, State University of Iowa.

Wednesday, June 16:

12:00 noon Business Meeting and Committee Reports.
Chairman: Professor Ralph T. Northrup, Chairman Division of Engineering Drawing, Wayne University.

2:00 p.m. Some Applications of Graphics in Engineering Problem Solving.
Chairman: Professor Stanley G. Hall, University of Illinois.

Technical Papers --

(a) "Graphics Applied to Problem Solving," Professor J. Howard Porsch, Purdue University.
(b) "Chart Distortion in the Construction of Nomograms," Professor Clyde H. Kearns, The Ohio State University.
(c) "Descriptive Geometry Problems Solved by Rotation About Normal Lines," Professor Albert Jorgensen, University of Pennsylvania.

N-DIMENSIONAL DESCRIPTIVE GEOMETRY

by
Professor Steven A. Coons
Massachusetts Institute of Technology

1. Descriptive geometry furnishes a technique for representation and manipulation of the common space elements, points, line, and plane. Based on this discipline, we may represent and deal with any functions of three variables, since such functions may be represented as curvilinear surfaces in space.

Since many functions have more than three variables, we need to extend the principles of descriptive geometry to spaces of higher than three dimensions, to enable us to represent such functions. In order to do this, we must investigate elements of higher order than points, lines, and planes, and establish fundamental descriptive geometry constructions which are extensions of those of three dimensions.

Since we possess recognized names for only the first three elements of a geometry, we shall classify elements of higher order as "linear manifolds." These, together with suitable methods of graphical representation, will constitute the bases for our generalized descriptive geometry.

For clarity, much of the argument will be carried out in a space of four dimensions, for if we break the bounds of our ordinary three dimensional universe, we enter the domain of all the higher dimensions, and what we learn about four dimensional space may easily be extended.

In this higher geometry, we shall encounter such curiosities as planes which appear as points, analogous to point views of lines; edge views of three dimensional spaces, in which the entire space appears as a line; skew planes, or planes which are neither parallel nor intersecting; four or more mutually perpendicular lines, and many other geometrical situations which are scarcely susceptible of visualization.

We shall begin the discussion with an examination of linear manifolds, the extension of the elementary space elements.

2. The single linear equation having as variables x_1, x_2, and x_3:

$$0 = a_0 + a_1 x_1 + a_2 x_2 + a_3 x_3$$

represents a plane in three dimensions. In a geometrical sense, it represents the locus of a point moving with two degrees of freedom, since if any two of the three variables x be arbitrarily chosen, then the third variable will be uniquely determined.

Two such equations, taken together, represent a line:

$$0 = a_0 + a_1 x_1 + a_2 x_2 + a_3 x_3$$

$$0 = b_0 + b_1 x_1 + b_2 x_2 + b_3 x_3$$

These equations represent the locus of a point which moves with one degree of freedom, because if we assign some fixed value to any one of the x variables, then the other two variables are immediately fixed also.

Similarly, three equations in three variables

$$0 = a_0 + a_1 x_1 + a_2 x_2 + a_3 x_3$$

$$0 = b_0 + b_1 x_1 + b_2 x_2 + b_3 x_3$$

$$0 = c0 + c_1 x_1 + c_2 x_2 + c_3 x_3$$

represent a point, a geometrical entity with zero degrees of freedom, since the three equations may be "solved" simultaneously to yield the three coordinates x_1, x_2, or x_3 in one and only one way.

As interesting special cases, we may have

$$x_1 = a$$

a single equation; if our space is three dimensional, this represents a plane. We may have

$$x_1 = a$$
$$x_2 = b$$

these two equations represent a point in two dimensions, or a line in three dimensions.

Finally, the three equations

$$x_1 = a$$
$$x_2 = b$$
$$x_3 = c$$

represent a point in three dimensions. We may think of these as though they were the more general equations with certain coefficients zero.

If we now extend these ideas, we may have, for instance, e equations in n variables,

x_1, x_2, x_3, ... x_n:

$$0 = a_0 + a_1 x_1 + a_2 x_2 + \dots + a_n x_n$$
$$0 = b_0 + b_1 x_1 + b_2 x_2 + \dots + b_n x_n$$
$$\dots\dots\dots\dots\dots$$
$$0 = m_0 + m_1 x_1 + m_2 x_2 + \dots + m_n x_n$$

This set of linear equations represents the locus of a point in an n-dimensional space, with a certain number of degrees of freedom. We have seen in the three dimensional cases that the degrees of freedom d, equals the number of variables, or dimensions, 3, minus the number of simultaneous linear equations, e:

$$d = 3 - e.$$

This relationship may be extended, so that for e equations in n dimensions, the degrees of freedom d are given by

$$d = n - e.$$

(Continued on page 24)

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(Continued from page 21)

As soon as we enter spaces of more than 3 dimensions, we run out of names for the geometrical entities that these combinations of dimensions and equations represent; the point, line, and plane symbols no longer suffice, so we need a new system of symbols. We shall call the geometrical entities represented by systems of linear equations "linear manifolds." The two characteristics of these manifolds of greatest interest are the number of dimensions, and the number of degrees of freedom, and we shall symbolize a typical manifold as an

$$L_d^n$$

where the superscript "n" gives the number of dimensions of the space in which the manifold is immersed, and the subscript "d" gives the number of degrees of freedom of a point in the manifold.

For example, a point in three dimensions is represented by the symbol

L_0^3; (i.e. 3 dimensions, no degrees of freedom)

a line is

L_1^3; (i.e. 3 dimensions, one degree of freedom)

and a plane is

L_2^3.

We may read the symbol L_d^n as "the linear manifold with d degrees of freedom in an n-dimensional space" or "the linear manifold of dimension n and degree d."

In a space of n dimensions, L_n^n represents the entire space, since it implies that the x_i are free to take on any arbitrary values independent of one another, and without restrictions imposed by any equations, since $e = 0$.

3. Consider the linear manifolds L_0^4 which are simply points in S_4. Such points may be represented by the symbol $P(x_1, x_2, x_3, x_4)$ to indicate that they have four fixed coordinates. We may have four points in S_4 so chosen that three coordinates vanish at a time:

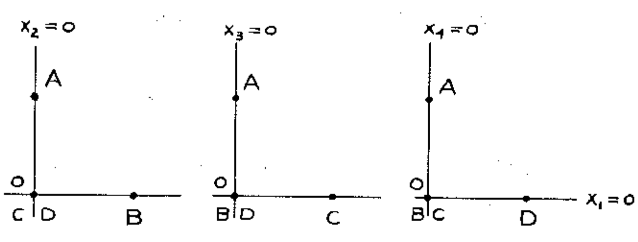
A(1, 0, 0, 0)

B(0, 1, 0, 0)

C(0, 0, 1, 0)

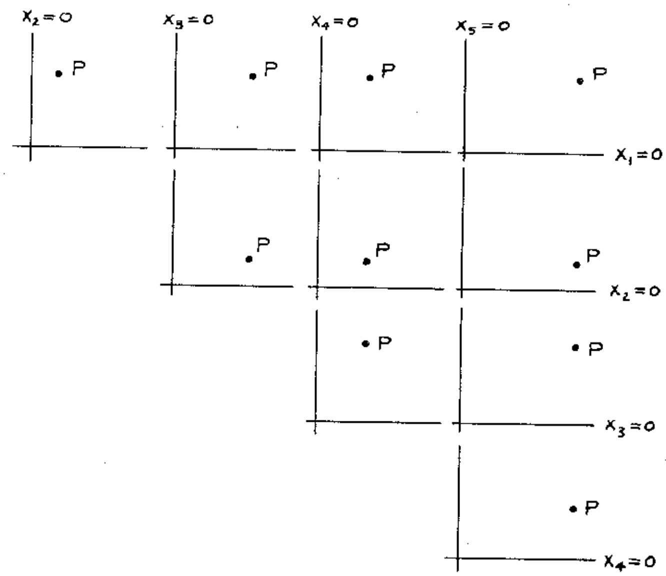
D(0, 0, 0, 1)

We may represent these points together with the point O(0,0,0,0) in three graphs with a common coordinate:



Although we are here discussing L_0^4, it is clear that similar graphs may be drawn to describe L_0^n for any number of n of x_i coordinates. We may represent points in a space of n dimensions by means of n - 1 graphs, with one coordinate common to all.

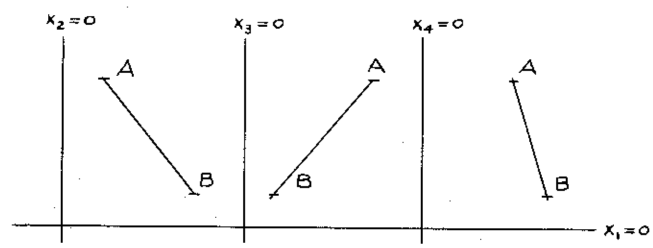
4. <u>A Point in 5 Dimensions.</u>



Using four graphs, a five dimensional extent may be represented. From these four definitive graphs, all other graphs each showing two dimensions may be obtained, by "projection," just as in the case of ordinary descriptive geometry. In the figure, the point P is defined in the two dimensional graphs $x_1\ x_2$, $x_1\ x_3$, $x_1\ x_4$, $x_1\ x_5$, from which by eliminating x_1, we obtain the graphs $x_2\ x_3$, $x_2\ x_4$, $x_2\ x_5$.

Again eliminating x_2, we obtain $x_3\ x_4$ and $x_3\ x_5$, and finally, by eliminating x_3, we arrive at $x_4\ x_5$.

5.



In S_4, assume that we have two distinct points, A and B. If in each graph of the two points we connect them by a line, we have a representation of an L_1^4; a linear manifold of four dimensions with one degree of freedom. This is to say that it is represented by three linear equations in the four variables:

$$0 = a_0 + a_1\ x_1 + a_2\ x_2 + a_3\ x_3 + a_4\ x_4$$

$$0 = b_0 + b_1\ x_1 + b_2\ x_2 + b_3\ x_3 + b_4\ x_4$$

$$0 = c_0 + c_1\ x_1 + c_2\ x_2 + c_3\ x_3 + c_4\ x_4$$

We may eliminate from this set of three equations two x_i at a time, yielding $\binom{4}{2} = 6$ equations each involving two x_i. Any set of three such equations also represents the L_1^4. Thus the equations.

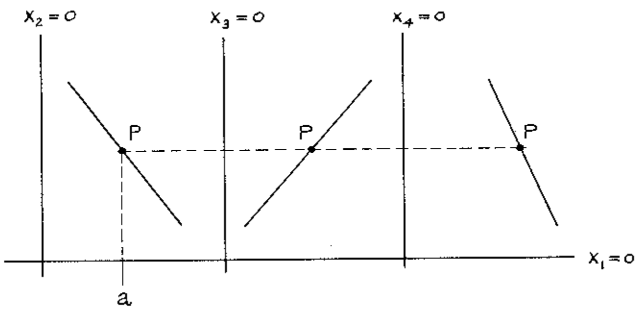
$$0 = A_0 + A_1 x_1 + A_2 x_2$$

$$0 = B_0 + B_1 x_1 + B_3 x_3$$

$$0 = C_0 + C_1 x_1 + C_4 x_4$$

may be obtained from the original set of equations by elimination of suitable x_i, and these three equations are equivalent in meaning to the original set; they are also the equations for each of the graphs. This furnishes a striking analogy between the number of equations needed to represent a manifold, and the number of graphs needed to represent the manifold from a graphical point of view.

6. An L_1^n may be called a line. We may fix some coordinate in one of the three graphs of the line. Then all other coordinates are also fixed, and we obtain a single point:



Thus if we fix the coordinate x_2 by setting

$$x_2 = a$$

it is seen that the point P is uniquely located on the line AB, and the coordinates x_1 x_3 x_4 are thereby fixed also. But in our notation, the single equation

$$x_2 = a \text{ is an } L_3^4$$

so that we observe that the intersection of an L_1^4 and an L_3^4 yields an L_0^4, in this case. We may formulate the tentative conjecture that this is always the case for all intersections of L_1^4 and L_3^4, so that we may always expect L_0^4 as the result.

Indeed, L_{n-1}^n and L_1^n represent manifolds analogous to L_3^4 and L_1^4, but in n dimensions, the first defined by one equation, the second by n-1 equations. If we cause these manifolds to intersect, we obtain a new manifold with 1 + (n - 1) equations, which, as we have seen, is an L_0^n, since it has precisely n equations in n dimensions. This will become clear in what follows.

7. We have generalize this notion of the intersection of two manifolds.

Write $$L_{d_1}^n \cap L_{d_2}^n \longrightarrow L_{d_3}^n$$

to read: "the intersection of $L_{d_1}^n$ and $L_{d_2}^n$ in n-space yields the manifold $L_{d_3}^n$." (We have borrowed the symbol " $\cap$ " from algebra). We wish to deduce the relationship of d_1, d_2 and d_3.

By definition of d, we have

$$d_1 = n - e_1$$

$$d_2 = n - e_2$$

where e_1 and e_2 are the number of equations needed to represent each of the two manifolds. Then the intersection of these manifolds yields $e_3 = e_1 + e_2$ equations, which define a manifold of degree d_3:

$$d_3 = n - e_3 = n - (e_1 + e_2) = n - (n - d_1 + n - d_2)$$
$$= - n + d_1 + d_2.$$

We have thus obtained the general intersection equation:

$$L_{d_1}^n \cap L_{d_2}^n \longrightarrow L_{-n + d_1 + d_2}^n$$

In the plane, n = 2, and two lines L_1^2 intersect to yield a point:

$$L_1^2 \cap L_1^2 \longrightarrow L_{-2+1+1}^2 = L_0^2.$$

But two points do not intersect, since

$$L_0^2 \cap L_0^2 \longrightarrow L_{-2+0+0}^2 = L_{-2}^2.$$

We shall postpone for the time being the meaning of manifolds with negative degrees of freedom, and say that they are undefined. We may say in passing that this is a hint of the principle of duality in n dimensions.

In ordinary 3 space,

$$L_1^3 \cap L_2^3 \longrightarrow L_{-3+1+2}^3 = L_0^3$$

or, a line intersects a plane in a point.

$$L_2^3 \cap L_2^3 \longrightarrow L_{-3+2+2}^3 = L_1^3$$

or, two planes intersect in a line.

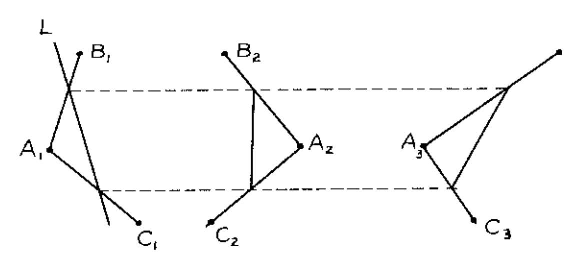
But $L_1^3 \cap L_1^3 \longrightarrow L_{-3+1+1}^3 = L_{-1}^3$ indicates that two lines in space do not intersect. Evidently intersection is a function of the space in which the manifolds are immersed.

With this device, we are prepared to investigate the nature of intersections in higher dimensions. Thus

$$L_3^4 \cap L_3^4 \longrightarrow L_{-4+3+3}^4 = L_2^4$$

says that two three dimensional spaces intersect in a plane in fourth dimension, a result which we would scarcely be able to visualize.

8.



If we have three points, we have seen that we may connect them by means of any two lines of the three possible ones, as for example lines AB and AC. If the three points define some manifold, of unknown degree d, then it may be symbolized as L^4_d. Now this manifold may be intersected by an L^4_3 shown in the first graph by line L, but not appearing in the other graphs. The intersection of L^4_d and L^4_3 yields an L^4_1 since it is determined by a line appearing in all three views.

Hence

$$L^4_d \cap L^4_3 \longrightarrow L^4_1 \quad \text{whence} \quad -4 + d + 3 = 1$$

But then d = 2, indicating that the manifold defined by 3 points is an L^4_2, a plane.

In general, if

$$L^n_d \cap L^n_{n-1} \longrightarrow L^n_1 \quad \text{then} \quad -n + d + n - 1 = 1$$

so d = 2.

9. Using this notion, we see that if

$$L^n_{d_2} \cap L_{n-1} \longrightarrow L_{d_1}$$

then

$$d_1 = -n + d_2 + n - 1$$

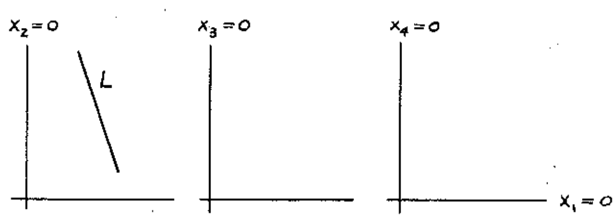
$$= d_2 - 1$$

or $d_2 = d_1 + 1$.

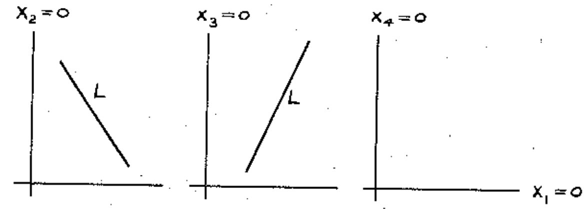
Hence a manifold of degree d is cut by a manifold of degree n - 1 in a manifold of degree d - 1. By repeated application of this rule, we may show that two L^n_0 define an L^n_1; three L^n_0 define an L^n_2; four L^n_0 define an L^n_3, and so on. In fact the L^n_i are independent of n, and i depends only upon the number of L^n_0, or points. K distinct points determine a manifold of K - 1 degree:

$$K\left(L^n_0\right) \longrightarrow L^n_{k-1}.$$

10. <u>Representation. Edge and Point Views.</u>

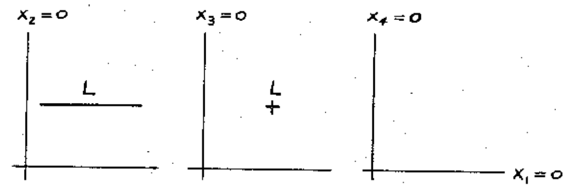


If L appears in only one view, but not in the others, e = 1, and d = n - e = 4 - 1 = 3. Hence L represents an L^4_3, a 3- space. The entire 3 space is represented by L, which may be called an "edge view."



Again, if L appears in two views, but not in the third, e = 2 d = 4 - 2 = 2 and L represents an L^4_2, a 2- space, or plane.

In this geometry, a plane can appear as a point:



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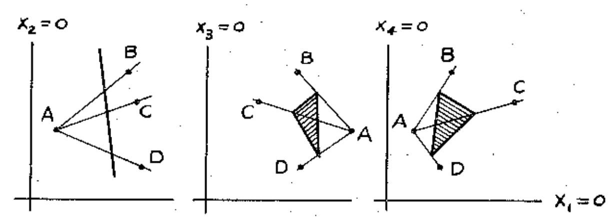


An L^4_3 is shown, defined by the points A, B, C, D. When cut by the L^4_3 represented by L, it yields the L^4_2 shown shaded.

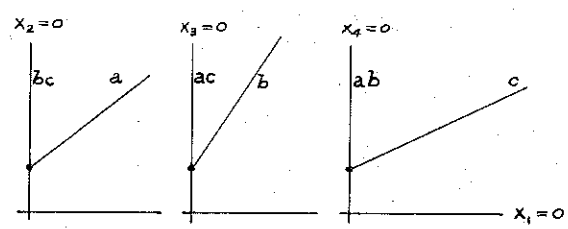
It is clear that the L^4_3 (A, B, C, D) may be cut by the three distinct L^4_3,

$$x_2 = 0$$

$$x_3 = 0$$

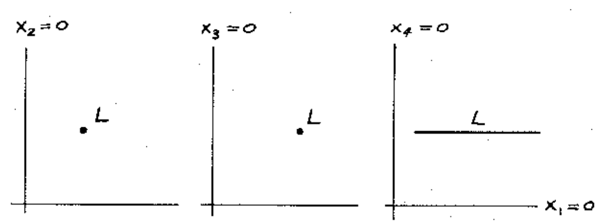
$$x_4 = 0$$

to yield a new representation for the original L^4_3:



These lines a, b, c may be thought of as the "traces" of the L^4_3.

12.



The manifold represented is an L_1^4 and in passing it is interesting to note that the third graph gives the true length of the manifold if length is defined by

$$l^2 = \Delta x_1^2 + \Delta x_2^2 + \Delta x_3^2 + \Delta x_4^2$$

because in this expression

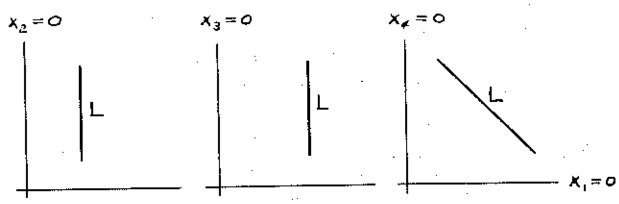
$$\Delta x_1 = 0$$

$$\Delta x_2 = 0$$

$$\Delta x_3 = 0$$

so that $l = \Delta x_4$.

Similarly, a manifold may have the appearance



and again the third view shows the true length.

13. In a space of n dimensions, there can exist the manifolds

$$L_0^n, L_1^n, L_2^n \ldots L_{n-1}^n.$$

All problems involving intersections in this space are solved by the use of "cutting" L_{n-1}^n manifolds, just as cutting planes are used in 3-space. The general process may be indicated. First, any manifold may be represented by combinations of L_0^n, which may then be connected by L_1^n's. If two manifolds defined thus by lines L_1^n intersect, we may cut them both by means of cutting manifold L_{n-1}^n, shown as a line in one view only - (what we have called the edge view of the manifold). This cutting manifold L_{n-1}^n will of necessity cut all lines of the other two manifolds, for

$$L_1^n \cap L_{n-1}^n \longrightarrow L_{-n+1+n-1}^n = L_0^n, \text{ points},$$

This set of points obtained by the cutting manifold L_{n-1}^n lies entirely within the manifold; that is to say, it lies in n-1 space of tbe manifold. Moreover, if one of the original manifolds is L_d^n, its section by L_{n-1}^n is L_{d-1}; that is, it possesses one less degree of freedom. Hence the original problem of intersection of L_{d-1}^n and L_{d-2}^n bas been reduced by means of the cutting manifold L_{n-1}^n to the new problem of intersection of the manifolds $L_{d_1-1}^{n-1}$ and $L_{d_2-1}^{n-1}$.

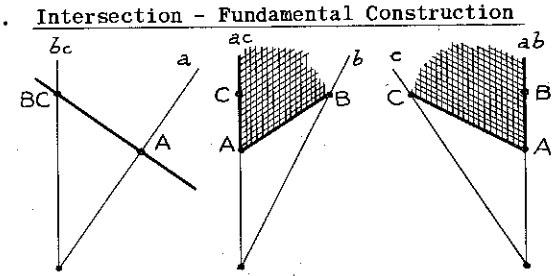
In the familiar case in 3-space of the intersection of two planes, each an L_2^3, we use a cutting plane to yield two lines, L_1^3.

But both these L_1^3 lie in the cutting plane, and hence we have to find the intersection of two L_1^2 which yield an L_0^2. Moreover, since the original problem yields

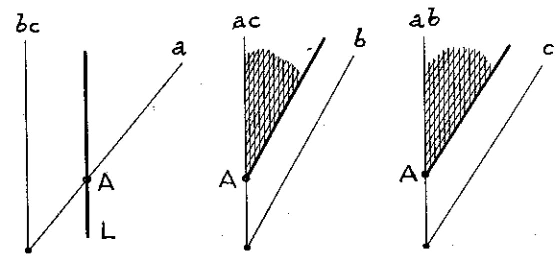
$$L_2^3 \cap L_2^3 \longrightarrow L_1^3$$

that is, the planes intersect in a line, it follows that we must find two distinct L_0^2 to define the line. Hence we must use two distinct cutting planes, each good for one point.

14. <u>Intersection - Fundamental Construction</u>



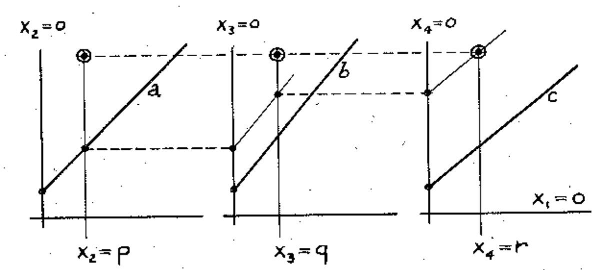
We know that two L_3^4 manifolds intersect in an L_2^4. If one of the L_3^4 is given by the three lines a b c, and the other by the line L, the intersection is the plane A B C, given by its traces.



Here the L_3^4(L) has been chosen so that points B and C are ideal points - the plane, as before, is given by its traces.

15. <u>Intersection of an L_1^4 with an L_3^4</u>

$$L_1^4 \cap L_3^4 \longrightarrow L_0^4$$



Let the L_3^4 be represented by the three traces a, b, c, and the L_1^4 by the equations

$$x_2 = p$$

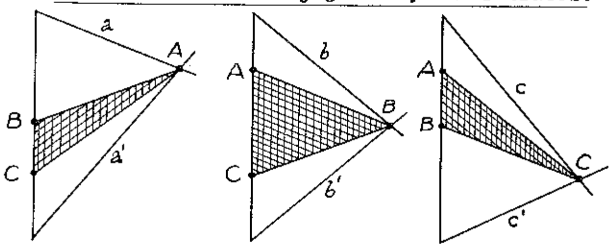
$$x_3 = q$$

$$x_4 = r$$

As before, the $x_2 = p$ manifold intersects the a b c manifold in a plane, and we may find the intersection of this plane with

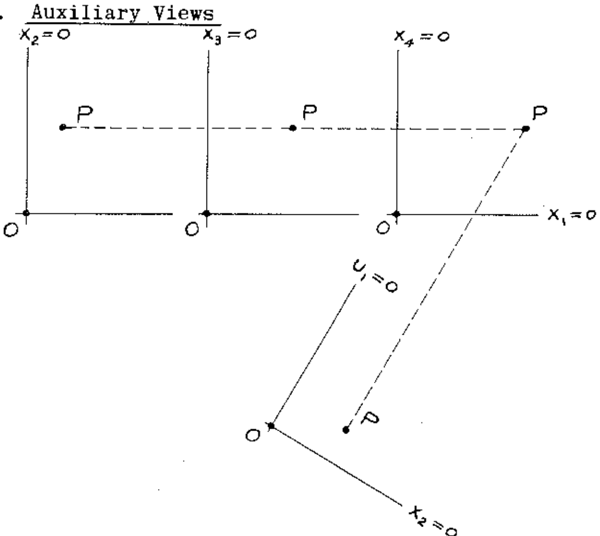
$$x_3 = q, \qquad x_4 = r.$$

16. Intersection - two L_3^4 given by their traces.



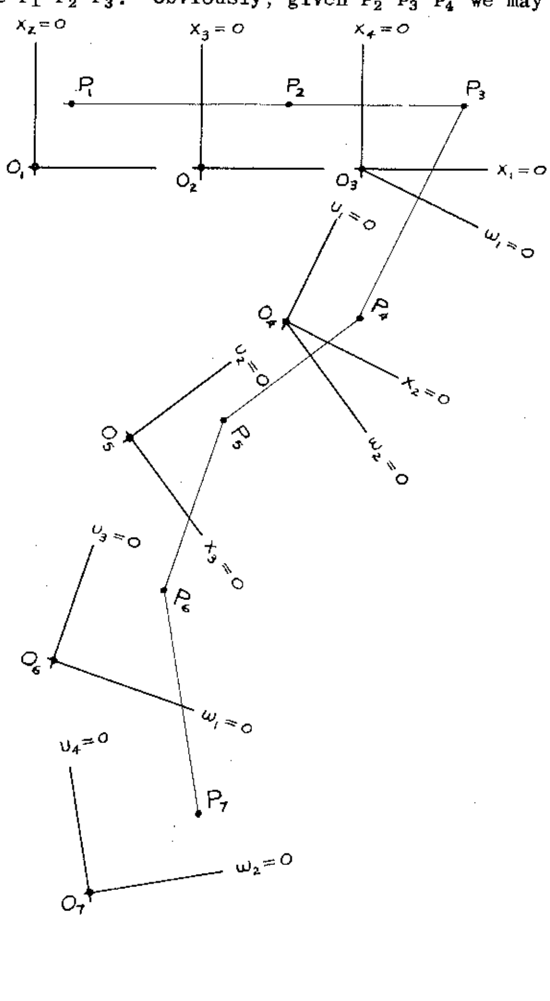
The L_3^4 (a b c) and L_3^4 (a' b' c') intersect in the L_2^4 (A B C) plane.

17. Auxiliary Views



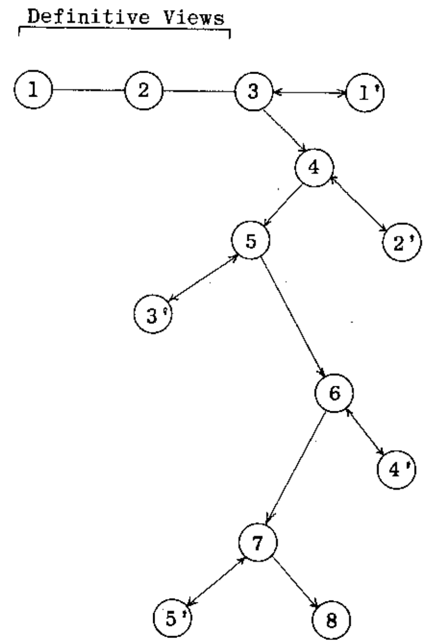
We may introduce a new coordinate u_1 into a system x_1 x_2 x_3 x_4. When this is done, the three graphs P_2 P_3 P_4 are equivalent in content of information to the original graphs P_1 P_2 P_3. Obviously, given P_2 P_3 P_4 we may find P_1.

18.

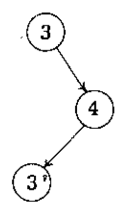


The process has been carried farther. Given P_2 P_3 P_4 we may find P_5; but we may reverse the procedure, and given P_5 P_4 P_3 we may find P_2.

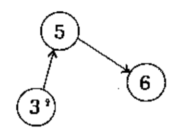
19. Scheme of Projection



The accented views 1' 2' 3' 4' 5', may be constructed by taking information from the corresponding unaccented view. Then the sequences



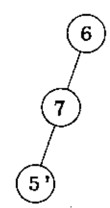
and



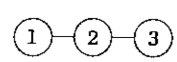
are the same as for ordinary descriptive geometry, and this idea may be used in constructing proofs for n dimensional descriptive geometry projections.

It is to be understood that these accented views are really not needed, except as they help to understand n dimensional projection in terms of 3 dimensional projection, and they would ordinarily be omitted.

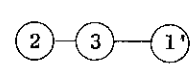
We may point out, however, that three views in the sequences such as for example



have the same significance as the original views

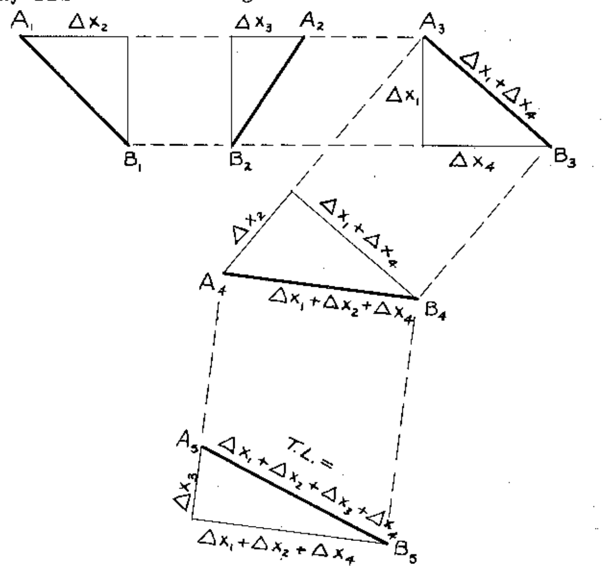


or



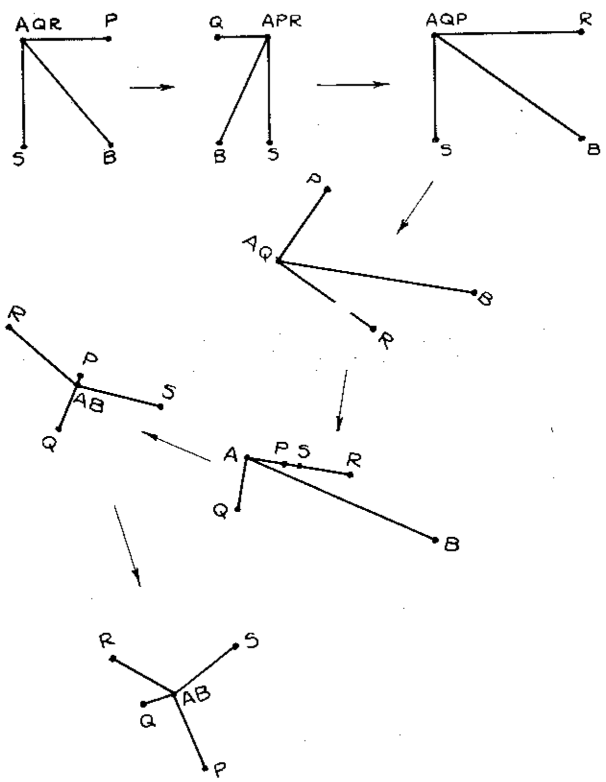
except that the coordinates have been transformed.

20. Using this scheme for constructing auxiliary views, we may find the true length of a line:

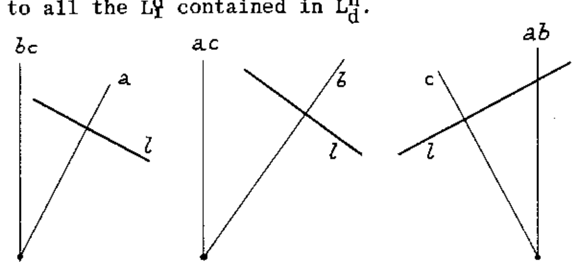


Vectorially, $\overrightarrow{AB} = \overrightarrow{\Delta x_1} + \overrightarrow{\Delta x_2} + \overrightarrow{\Delta x_3} + \overrightarrow{\Delta x_4}$ which has been constructed.

21. View of the four mutually perpendicular lines AP, AQ, AR, AS taken in the direction AB; (application of point view of a line.)



22. Perpendicularity:
A line is perpendicular to an L_d^n if it is perpendicular to all the L_1^q contained in L_d^n.



$L_1^4(l)$ is perpendicular to L_3^4 (a b c). Lines a b c each show T.L. in one view. Line l is perpendicular to these T.L. lines, and hence l is perpendicular to these lines in 4-space. We need now only show that l is perpendicular to all lines of L_3^4 (a b c).

PROCEEDINGS OF GRAPHICS CONFERENCE

Proceedings of the conference on Engineering Graphics held at Purdue University in November, 1953, have been published. Copies are available if 50 cents is remitted to G. A. Hawkins, Director Engineering Experiment Station, Purdue University, Lafayette, Indiana, with a request for Graphics Conference Proceedings.

The papers included are:

Introduction to Engineering Graphics
Delineative Representation
Problem Solutions
Computing Devices
Reproduction Processes

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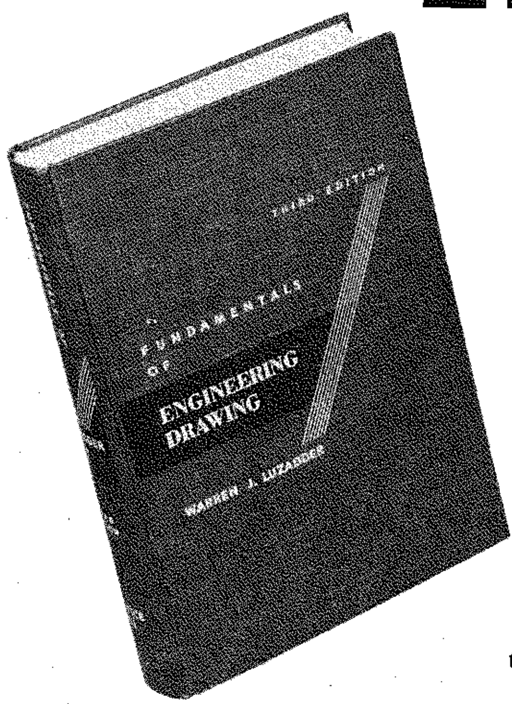

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CAVE CANEM

by

Dr. Ellis Blade, P.E.

Consulting Engineer

Apparently some dogs are smarter than some men.

It's certainly a smart dog that knows where to put on the bite, but even so, Fido must have looked at that blueprint long and hard before gulping. Did he really know his Euclid, or had the boss carelessly spilled his lunch gravy right over the middle (sic) of the drawing?

But let chewing dogs sleep, for the restoration takes a bit of dogging, too. Meanwhile, we're burning to view Fido's own amends for his mischief.

The practical dog would eschew Euclid, preferring a good approximate solution based on modern ways, or even a good analytical calculation. He would probably suspect the accumulation of errors inherent in the large number of successive operations required in the exact solution by straightedge and compass.

Moreover, it might as well be admitted that the straightedge and compass solution probably would never have occurred to Euclid's dog.

The only pertinent geometric fact seems to be the equality of distances of corresponding points back of their respective reference lines. Only two of these equalities are significant, since the third is obtainable from the other two, by subtraction. Let the reference line be drawn through one of the vertices, say point B, since this involves no loss in generality. Then, considering either view, let the projectors be AA"A' and CC"C'; and let the reference line be A"BC". The letters do not necessarily occur in that order, but depend on the orientation of the reference line. (Fig. I)

Let BA = a, and BC = c. Let the interior angle at vertex B also be designated by B. Let angles opening in the sense of BA toward BC be reckoned positive, and call Z the angle between BA and BA". Then the angle CBC" is Z - B, or else it is π - (Z - B). In either case, AA" is a sin Z. Call it p. Also CC" is c sin (Z - B). Call this q.

Approximate solution.

Considering either triangle, draw the projectors AA', etc., in various directions, and for each direction measure p and q. Plot q as a function of p, using rectangular coordinates. The result is an ellipse, which in general lies at some angle to the p and q axes.

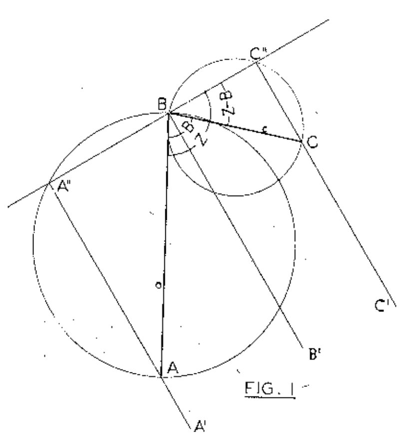


FIG. I

Now repeat the same procedure for the other triangle, and plot its q against p, using the same p axis as before. The result is another ellipse, in general lying at a different angle than the first, and intersecting the first one in four places. At each of these places, $p_1 = p_3$, and $q_1 = q_3$. There are two distinct values, for the third and fourth intersection repeat the results of the first two intersections, with opposite sign.

In each projection, draw circles with BA and BC as diameters. Lay off chords of lengths p and q from A and C respectively. The continuation of these chords are the required projectors AA', etc. The unknown intermediate view $A_2B_2C_2$ is of course found by intersection, there being two distinct solutions.

Exact solution.

The approximate solution depends on the intersections of two ellipses. There is another solution, based on the intersections of two circles, which can be accomplished entirely by straightedge and compass. It is also the appropriate analytical solution, and is based on the two equations

$$A_1 \sin Z_1 = A_3 \sin Z_3$$

$$C_1 \sin (Z_1 - B_1) = C_3 \sin (Z_3 - B_3)$$

When Z_3 is eliminated from these two equations, the result is

$$A_1^2 C_3^2 - 2 A_1 A_3 C_1 C_3 \cos B_1 \cos B_3 + A_3^2 C_1^2 - 2 A_3^2 C_3^2 \sin^2 B_3$$

$$= \begin{bmatrix} A_1^2 C_3^2 + A_3^2 C_1^2 (\cos^2 B_1 - \sin^2 B_1) \\ -2 A_1 A_3 C_1 C_3 \cos B_1 \cos B_2 \end{bmatrix} \cos 2 Z_1$$

$$+ 2 A_3 C_1 \sin B_1 \begin{bmatrix} A_3 C_1 \cos B_1 \\ -A_1 C_3 \cos B_3 \end{bmatrix} \sin 2 Z_1$$

Call the left member of this equation R_1, and draw a circle about the origin, of radius R_1. Call the right

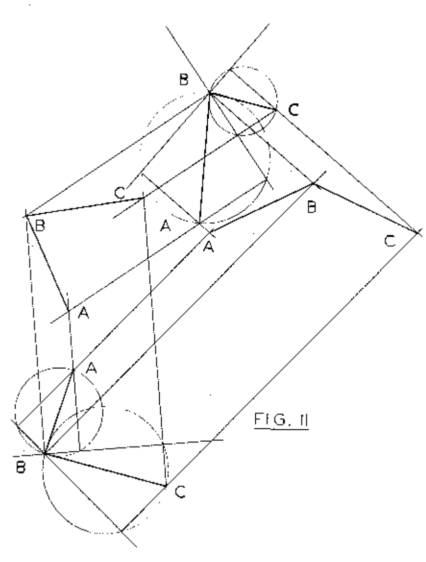


FIG. II

member R_2, and note that this member depends on the variable $2Z_1$. In fact, if $2Z_1$ is interpreted as a polar angle, the locus of R_2 in polar coordinates, in a circle, passing through the origin. This circle is of the form

$$R_2 = M \cos 2Z_1 + N \sin 2 Z_1$$

$$= \sqrt{M^2 + N^2} \cos (2 Z_1 - X)$$

where X is the phase angle, known from tan X = B/A.

The two circles intersect in two places, corresponding to the two values of $2Z_1$ that satisfy the problem.

The two circles are drawn with the compass. All the coefficients in the two circle equations are found by simple operations of multiplying, adding, and subtracting the lengths given in the original problem. Hence the whole solution can be done by straightedge and compass alone, which was Euclid's requirement.

Give that dog Fido a bonus.

FIDO'S CHEW PROBLEM

by

R. A. Jewette

University of Illinois

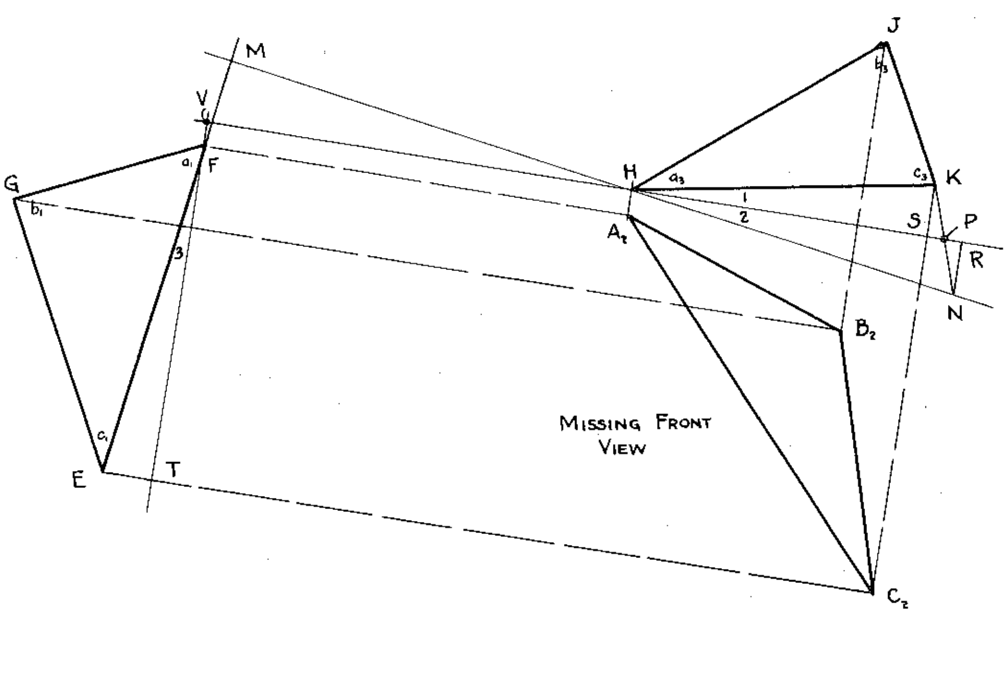
GIVEN: $\triangle\, a_3b_3c_3$ LABELED $\triangle$HJK.

$\triangle\, a_1b_1c_1$ LABELED $\triangle$EGF

PROBLEM: TO LOCATE 2 GROUND LINES, HV & VF, ⊥ TO EACH OTHER SO THAT KS = ET

PROOF:

	Statement		Reason
1.	FROM PT. H, DROP ⊥ (HM) TO EF EXTENDED.	1.	ONLY ONE ⊥ CAN BE DRAWN FROM A PT. TO A GIVEN LINE.
2.	EXTEND MH TO SOME PT. "N", SUCH THAT HN = FE.	2.	BY CONSTR.
3.	DRAW LINE KN.	3.	2 PTS. DETERMINE A STR. LINE.
4.	BISECT KN AT PT. "P."	4.	BY CONSTR.
5.	DRAW LINE HP.	5.	REASON #3.
6.	DROP ⊥ (KS) FROM PT. "K" TO HP. DROP ⊥ (NR) FROM PT. "N" TO HP.	6.	REASON # 1
7.	KS ∥ RN	7.	LINES ⊥ SAME LINE ARE ∥.
8.	KP = PN	8.	STEP 4 - DEFINITION OF BISECTOR.
9.	∠KPS = ∠NPR	9.	VERT. ∠s =
10.	∴ RT. △ KPS ≅ RT. △ NPR	10.	HYP. ∠ = HYP. ∠
11.	∴ KS = RN	11.	CORR. SIDES ≅ △s ARE =
12.	DROP ⊥ (FV) FROM PT. "F" TO PH (EXT.)	12.	REASON #1.
13.	DROP ⊥ (ET) FROM PT. "E" TO VF (EXT.)	13.	SAME
14.	∴ ∠3 = ∠2	14.	2 ∠s WHOSE INITIAL & TERMINAL SIDES ARE RESP. ⊥ ARE =.
15.	EF = HN	15.	STEP #2.
16.	∴ RT. △ FTE ≅ RT. △ HRN	16.	REASON #10.
17.	∴ ET = RN	17.	REASON #11
18.	∴ ET = KS	18.	THINGS = SAME THING = EACH OTHER.



WHAT DO YOU MEAN "DIRECT" OR AN OLD FOGEY STRIKES BACK

by

Professor Henry C. T. Eggers
University of Minnesota

In the article "The Transfer of Ideas to Aid in Creative Thinking" by Professor McNeary in the November, 1953 edition of the Journal of Engineering Drawing, appeared this statement:

"The gradual shift in the teaching of descriptive geometry from the indirect, or plane trace method, to the direct, or auxiliary view method, logically may be claimed to have been caused by the superior transferability of the direct method to engineering practice. This is so because the auxiliary view method may be used easily in practice by anyone familiar with the principles of orthographic projection, while the concept of representing a plane by traces is an artificial one that is applied to most practical problems with difficulty."

"In this connection, it is interesting to note that most engineering educators aged forty and over were trained in the indirect method and may not be aware of recent developments in descriptive geometry. It is important that these men be informed because they are most influential in building curriculum."

Since, no doubt, others besides myself violently disagree with some of Professor McNeary's statements as well as with its implications, some comment is necessary to clear the atmosphere a little. The statement quoted is indicative of a lot of rather peculiar thinking now prevalent not only in our own particular field, but in the world in general. There is a tendency at the present time to, shall we say, over-simplify. For instance, a person is classified either as: Republican or Democrat; a member of the classifier's church or a heathen; a Facist or a Communist; an Internationalist or an Isolationist. In politics we do occasionally hear about Independents and in ideologies we even hear about "Pinkos" or watered-down Reds. However, in general one is either good red fish or herring. Probably instead of using the word "over-simplify" I should have used the uglier, but more appropriate word "intolerant."

What has all this got to do with Descriptive Geometry? Simply this, we are faced with the situation in our own field where certain, no doubt well-intentioned, individuals are attempting not only to classify everyone in the field as either a so-called "Direct Method" person or as an "Indirect" or "Plane Trace" one, but also to promote the idea that the two methods are in direct conflict and the one must not be allowed to contaminate or interfere with the other.

Before commenting directly on some of Professor McNeary's statements I would like to record a few thoughts of my own which I feel are pertinent.

The first difficulty facing anyone involved in a controversy is caused by the limitations of the English language. We all have the habit of throwing words around with abandon and thus what we say can mean various things to various people. We should therefore be meticulous in the use of language and try to use terms whose meanings are clearly understood and clearly express the thoughts which we are attempting to convey. One term that particularly irks me is the word "Orthographic." Another is "Direct" when used to describe a method of graphically solving a three-dimensional space problem. Later I shall comment specifically on these two terms and give my reasons why I dislike them, and that my criticism may not be entirely destructive, I shall suggest what I feel might be better terms.

Just exactly what are we attempting to do in the teaching of Engineering Drawing? First and foremost, of course, we are endeavoring to put our subject matter across for the enlightenment and understanding of the student. Second, like all of the other teachers in our college, we are assisting in converting the raw product which we receive into a future Engineer. In teaching our own subject, therefore, we should continually keep in mind how the subject fits into the whole scheme of things and how to best present it so as to be of most use to the future Engineer in meeting his professional problems.

For the benefit of those who are so strong for simplification I might say that as teachers of Drawing we have only one problem to put across to our students: to represent the three-dimensional space in which we live on a two-dimensional surface. To do this we resort to so-called systems of representation. There are several such systems but most of us limit ourselves to a few of the so-called pictorial systems such as Isometric, Oblique, and Perspective, and to one system of the non-pictorial variety which usually is referred to as "Orthographic Projection."

We make use of these systems of representation for two main purposes:

1. For the communication of Engineering information.

2. For the graphic solution of problems involving space relationships.

That part of our work pertaining to the transmission of information is usually referred to as "Engineering Drawing" and that part concerning the solution of space problems is generally called "Descriptive Geometry."

I have already said that I do not like "Orthographic" and the reason I do not is that to me it is a misnomer. I prefer, together with some other individuals, aged forty and over, to use the more informative "Orthogonal," because to me it represents a complete one-word description of the system. The term "Orthogonal" is derived from two Greek words; "Ortho" meaning "right" and "Gonal" meaning "angle." "Orthogonal" projection then means "right angle" projection. If a system of projection is "right angled," the projectors are at right angles to the plane of projection which of necessity forces all the projectors to be parallel and hence removes the "point of sight" to infinity. To those in our field who are so strong for simplicity I respectfully suggest we use "Orthogonal" which so correctly and beautifully describes a rather complicated system of projection in one word.

The pictorial systems of representation have the common advantage of being easy to visualize. They have the disadvantage that they contain distortion. Although less easy to visualize, "Orthogonal" projection has the distinct advantage of containing no distortion. For the latter reason "Orthogonal" projection is a convenient vehicle not only to transmit engineering information, but also to solve space problems.

Let us suppose, then, that a space problem is presented to us for solution. If the problem is presented in words we immediately have a choice as to whether to use algebra, trigonometry, analytic geometry, calculus, graphics, or what have you. If the problem is presented graphically we might or might not still have a choice, depending upon the nature of the problem. Chances are however, that we would work it graphically and start with the set up as given. If the vehicle of projection used is orthogonal projection, the problem usually occurs in either a so-called complete one-view drawing such as a contour map or in a two-view drawing. In the contour map we would probably confine ourselves to solving the problem in that one view. On the other hand, if the problem is given by means of at least two views, we have a choice between solving it in the views given, or constructing one or more additional views. If recourse is made to additional views the method is termed "Direct," "Auxiliary View," or "Multiple View." I like the term "Multiple View" but would even go along with Professor McNeary in accepting "Auxiliary View."

Solving by use of multiple views is practically as old as the subject of Descriptive Geometry itself. About twenty years ago Professor Hood applied the name "Direct" to the multiple view method and immediately some over-enthusiastic zealots latched on to it and started the propaganda that here was something new which made obsolete everything else and was a cure-all for all our ills.

I hasten to say that I have nothing against solving problems by the use of multiple views if it appears to be the best way to do it. It is a powerful method of attack for most space problems and can be used as a last resort if other methods do not suggest themselves. But to call the method "Direct" is a horse of another color. A good name should contain within itself its own definition, if possible. The name "Direct" does not give any information as to what it is, except to imply that any other method is indirect. For example let me again quote Professor McNeary; "The gradual shift in the teaching of descriptive geometry from the indirect or plane trace method, to the direct or auxiliary view method, ..." For certain problems, multiple views might offer the most direct method to use, but in other problems it might be the most indirect way to do it. Certainly if accuracy is a factor in the solution (which it usually is for problems solved graphically in an engineering office) it would at least be questionable to solve by five views where the two original views would suffice. I therefore suggest adopting one of the three terms "Multiple," "Auxiliary," or "Supplementary," as a more desirable replacement for the ambiguous misnomer "Direct."

Being an old man of sixty-one years and having taught the subject of Descriptive Geometry for thirty-five of those years, perhaps I should be permitted to give a little fatherly advice to the members of our division. Here it is: Let us not exhaust ourselves in going around knocking down windmills which do not exist anyway, but let us close ranks and save our energy to battle the prejudice and mis-information concerning our work by those on the outside.

In closing I would like to leave one more thought which is probably best expressed by this old Quaker saying:

"Every one in the world is queer but me and thee and sometimes I think thee is a little queer too."

GRAPHICS FOR NON-ENGINEERS

by

Professor Richard W. Parkinson

Ohio State University

The form of this message is a description of a situation involving the presentation of Engineering Drawing instruction to a group of students of non-technical background. This description is inspired by the hope that you may derive ideas suitable for similar instruction in your home institutions and that some of the techniques presented may find application in the area of instruction for engineering students.

I say in advance that I have no magic formulas for solving the manifold problems with which we are all familiar. I merely hope to provoke your thoughts and to point them in a certain general direction. I am confident that if enough reflection is devoted to any given situation, any of you gentlemen could arrive at a satisfactory conclusion without any help from me.

I now propose that the discussion of the course from which my experience has been drawn shall be developed along these lines:

a. Type of "customers"--where have they been, professionally speaking, and whither are they bound.

b. Overall objective of the program of instruction.

c. Scope of course

d. Techniques of instruction

e. General reactions and experiences

f. Other applications

It seems fundamental to me that any rational approach to the development of a course of instruction involves an immediate analysis of the students--their background and their probable or assumed professional destinations.

In the case in point the students are enrolled in the Industrial Management option of the Department of Business Administration, College of Commerce.

Conferences with the curriculum director of that program revealed the following essentials:

a. Graduates in Industrial Management are typically employed in the business end of a manufacturing industry. The industry may be anything from automobiles to soap chips and from diapers to Dixie cups.

b. They are normally not a part of an engineering department and are expected to do no design or drafting-room work themselves. (This is a crucial factor in our planning.)

c. They anticipate operating in the fringes of engineering, thus having occasion to interpret engineering paper work, especially drawings, which others have prepared. (This is another salient fact.)

d. The students' backgrounds are completely varied. Possibly a fourth of the class will have been exposed to engineering drawing either in high school or in commercial situations or will have had a little experience in industrial shops. Their mathematical histories usually show meagre training. All in all, they have, as might be expected, a technical background of noticeably lesser magnitude than is expected, or at least desired, of engineers.

With the foregoing items in mind it now becomes possible to define the objective of the instruction. It is the objective of this course to acquaint the students to the maximum extent with the subject matter of engineering drawing. This should result in tbe students' having at least an elementary ability to read and understand existing drawings and to ask intelligent questions about what they don't understand.

Any consideration of scope is inseparable from a decision about where to begin and how long do you have to accomplish your objective.

It was clear at once that instruction would have to commence at the beginning. The time available was one quarter which amounts to a maximum of 58 clock hours of contact for which 3 credits are awarded.

Further discussion with the sponsoring department resulted in the selection of the following blocks of subject matter for inclusion in the course: (For the statistically minded, the clock hours devoted to each are indicated)

a. Orthographic Projection.	21
b. Sections and Conventions	9
c. Pictorial Representation	4
d. Threads and Fasteners.	4
e. Dimensions and Tolerances.	4
f. Working drawing and blueprint reading. .	10
g. Slide Rule	3
h. Reproduction of drawings	2
i. Inspection trip to machine shop.	1
	58

To recapitulate, our problem was merely to present, in one quarter, a terminal course to students of no particular background so that they would have at least a minimum ability to feel their way through any ordinary engineering drawing, be it mechanical, architectural, or perhaps even otherwise.

Obviously there was no time for luxurious dalliance in the esthetics of the art. This instruction had to be approached with a new and ruthless frame of mind. Every problem, every assignment had to be scrutinized with a cold and unsympathetic eye--if an item did not contribute constructively to our aim of reading a drawing, it was remorselessly cast out.

The first and most obvious departure from the usual course for engineers is an almost complete lack of concern for "technique" or "draftsmanship." Only reasonable neatness is required, and even this is not involved in arriving at course grades. It is analogous to the situation wherein a theme submitted to the English Department must be readable, but beyond that its literary merit is unaffected by the quality of the handwriting.

This means, of course, that all problem material from orthographic projection through pictorial representation is handled by means of freehand sketches on coordinate paper. All other items are handled by means of "question and answer" or "reference" type problem sheets.

Title blocks and record strips may be filled in long hand--perhaps a shocking admission to a person steeped in tradition--but it goes without saying that a person's ability to letter does not improve his understanding of another's drawing.

I realize that the freehand sketch approach to the principles of orthographic shape description is already fairly widespread and will doubtless become more so, so no attempt is made to include examples of problem material. I shall, however, present a more detailed description of later phases of the course in order to clarify the meaniug of "question-and-answer" problem material.

In the threads-and-fasteners pbase, for example, the students are given all the information required for the specification of a thread or a fastener such as a cap screw. This data is served up in a scrambled form and the students' problem is to rewrite it in the proper order. Questions relating to the application of various styles of fasteners are included. Symbols are treated by sketching. Later the students are asked to glean screw thread information from completed drawings in order to enhance their facility for recognition.

Problem material on dimensions and tolerances involves computation of limits, tolerances and allowances, and the checking of completed drawings for errors and omissions in dimensions.

The program dealing with working drawings and blueprint reading takes the form of instruction on the organization of such a set of drawings followed by considerable practice in the interpretation of them. Each student is given a complete set of blueprints describing a machine assembly and all its components.

These prints are accompanied by a voluminous list of questions, the answers to which are to be found by a thorough combing of the drawings.

This same process is repeated with a partial set of drawings of one of our campus buildings, these drawings having been obtained from the office of the University Architect.

Slide rule instruction follows the conventional pattern of explanation and demonstration concluding with suitable problems for student performance. This instruction is limited to purely arithmetic operations since the students have no background in trigonometry and logarithms.

The reproduction of drawings involves a movie on the most common methods of commercial copying plus a display of materials such as multigraph plates, photostats, and ink tracings. A discussion of relative costs and volumes characteristic of each system is included.

The inspection trip mentioned is to the machine shops of the Industrial Engineering Department. A faculty member of that department conducts a preliminary conference on manufacturing methods and precision. He then conducts the class through the shops giving a brief resume of the principal characteristics and capabilities of each machine.

This instruction occurs at about the time the students are encountering dimensioning and working drawings in the classroom. Its purpose is to stimulate interest as well as to provide some background against which to view the impending course work.

A re-examination of the time allotted to each unit of subject matter reveals the accelerating pace at which the work progresses. Formal lectures and text assignments occur perhaps once per week in the early stages of the term, whereas by the time screw threads and dimensions are reached, a new topic is broached almost every other day. In fact a good portion of this course might possible be conducted on a lecture and homework basis without a fatal loss of effectiveness.

I would like to point out that the ultimate end of this experience, namely the development of the students' ability to read drawings, receives an even greater proportion of our class time than is indicated under this heading in my previous breakdown. The students are eased into reading orthographic views as such after about two weeks when the development of new orthographic views from existing views in the same system is begun.

They are more or less constantly in contact with this language for the rest of the term. The exercises employing bonafide blueprints represent the culmination of all that has gone before and create a sense of accomplishment in the minds of the students.

I hope the foregoing remarks have enabled you to formulate a kind of mental panoramic perspective of what happens in this program. I should like now to discuss briefly some of the side effects which have been observed during the past three or four years.

First, what about student reaction? It is difficult to be completely objective about this sort of thing; nevertheless, I feel that I may say with confidence that the course is very well received. The principal objection students have to the conventional drawing courses usually is due to the "labor factor" which is unavoidable if nicely executed instrument drawings are required. We are happily able to disregard all this, thus eliminating a considerable barrier.

Another policy, too often neglected, which we try to follow is to get the student in a happy frame of mind the first time the class meets. We save our best stories for that meeting and are at pains to convince the student that he is to be the recipient of material specially tailored to his individual needs. After all, teaching is not so much an overt act of instruction as it is the creation of an atmosphere which is favorable to learning. It is hardly news to anyone that if a student is sufficiently motivated, he will learn in spite of the best efforts of the teacher.

Discussions of an apparently diversionary nature, if kept within reasonable bounds, may not be directly constructive but may keep the student in such a receptive frame of mind that he anticipates each session with fair enthusiasm or at least an absence of resentment.

If this climate can be maintained each day, you won't have much trouble getting your ideas across.

Another feature of this type of instruction which, from the student point of view, is quite important is the comparatively low cost. It takes easily $35.00 out of a student's pocket to set him up for a formal drawing course. If a slide rule is required the ante rises accordingly. The equipment for the course under discussion costs about $12.00 <u>including</u> a pocket-sized slide rule. Both of these figures are exclusive of any fees payable to the bursar.

I come now to an item of information the significance of which is subject to considerable divergence of opinion. It has been our custom to give the student an opportunity at the end of the term to express his views concerning the value of the course and the manner of presentation. A simple, mimeographed form is provided to make this as easy as possible. The following are some excerpts from data we have accumulated from recent classes in the Industrial Management curriculum:

	Percent Response		
	Good	Fair	Poor
Overall Value	91	9	0
Content	79	21	0
Order of Presentation	91	9	0
Problem Material	88	12	0
Examinations	80	20	0
Inspection Trip	82	18	0

The questionnaire also contains a section pertaining to the students' evaluation of the instructor's performance. I have intentionally omitted a resume of this data because its character is so profoundly affected by the instructor's personality that it would lack meaning in other circumstances.

As you can see, the above tabulation indicates a very favorable reception by the students.

Educators have tended to view student evaluations with some scorn. There is doubtless some justification for this attitude when the students being queried are freshmen and therefore have as yet insufficient background against which to make valid comparisons. In this case, however, the average class rank of the students is a little more than junior. If maturity of judgment is ever to be developed it is reasonable to expect that it has occurred to an appreciable extent by this time. I am inclined, therefore, to accept these opinions at approximately their face value. Surely if such a survey showed a decidedly unfavorable complexion it would be high time to mend one's fences.

I would like next, and finally, to speculate upon the potentialities of the philosophy whose physiognomy I have endeavored to depict.

In the first place I hope you may discover opportunities at home to preach the gospel of engineering drawing to groups of students similar to the one herein discussed. Other students who could benefit from such instruction are those in patent law and the technological branches of medicine, dentistry, and agriculture. I realize that if such curricula do not already include a course in graphics it would be a tremendously difficult proposition to sell the idea to the powers that be. Degree-giving departments are usually interested in reducing, rather than increasing, the number of so-called basic courses. Still, the fact that it might be difficult to install does not detract from the intrinsic worth of the idea. My chief thesis is, "Have you thought about it?" There may be hitherto unsuspected opportunities existing if we can only capitalize on them.

Is there an application of this philosophy to already-established courses in engineering drawing? There can hardly be doubt.

We are all acutely aware of the pressure being put on drawing departments all over the country. These forces are due to numerous causes and do not necessarily imply dereliction on the part of the service departments. The major departments are continually faced with the problem of increasing the graduate level content of their curricula. This is particularly true of those departments who have espoused the so-called "combined" program.

The inevitable result of such pressure is that the stress is conveyed, as in any sound structure, to its foundation where is found the engineering drawing program.

If our departments must yield, as it seems we many times must, we must resort to new and constructive techniques, we must streamline our methods so as to preserve the integrity and validity of our subject matter--the alternative is extinction.

I have attempted to describe to you the problem of imparting engineering drawing instruction to the non-technical student as personified by our Industrial Management majors. I have indicated, in broad outline, that our approach is aimed exclusively at subject matter. I have tried to show how our coverage has been increased and rendered more palatable, how student reception has apparently been good.

I have endeavored to apply these principles to instruction designed for students in other fields, especially engineers.

I have spoken of the need for liaison with the department being served, before, during, and after the presentation of course material. I cannot overemphasize the importance of this and that it should be at the initiative of the service department.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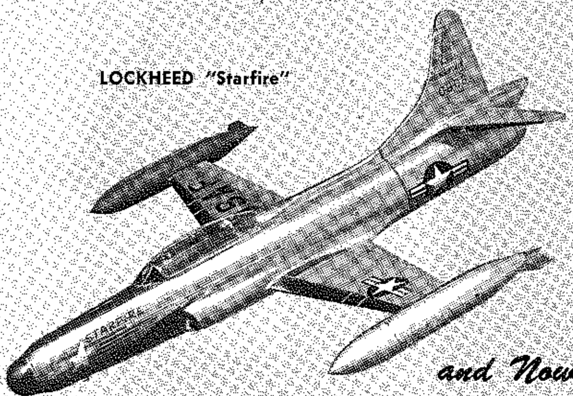

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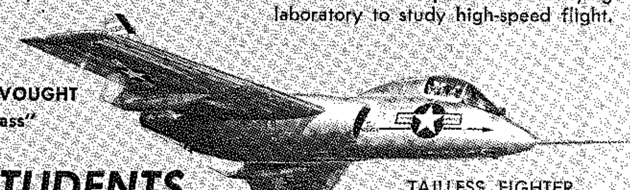

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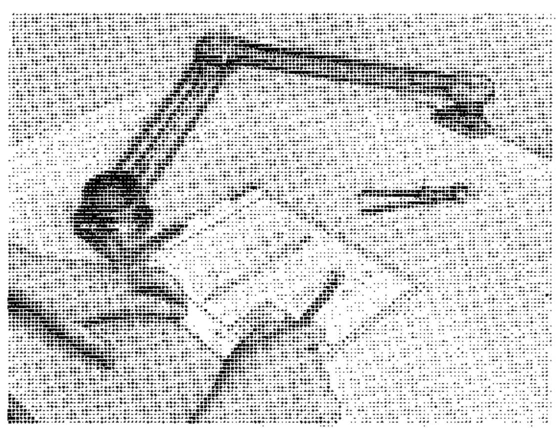

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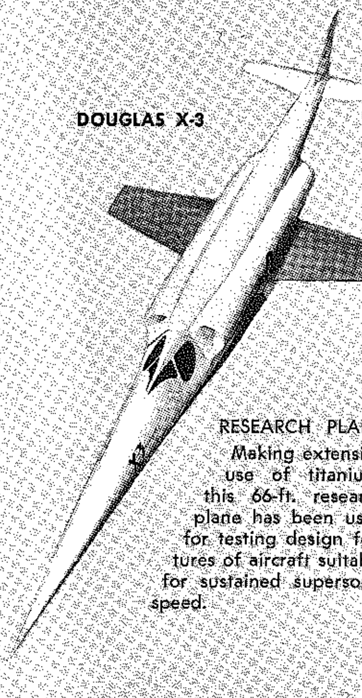

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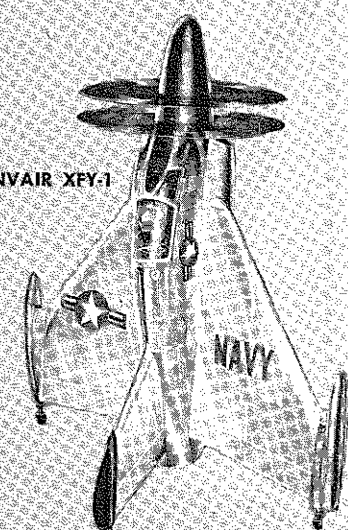

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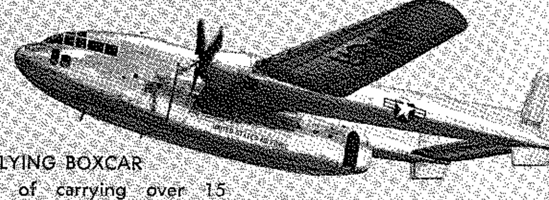

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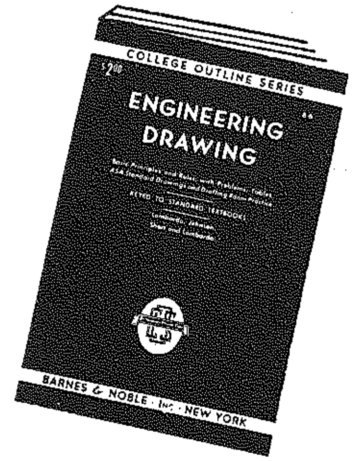

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