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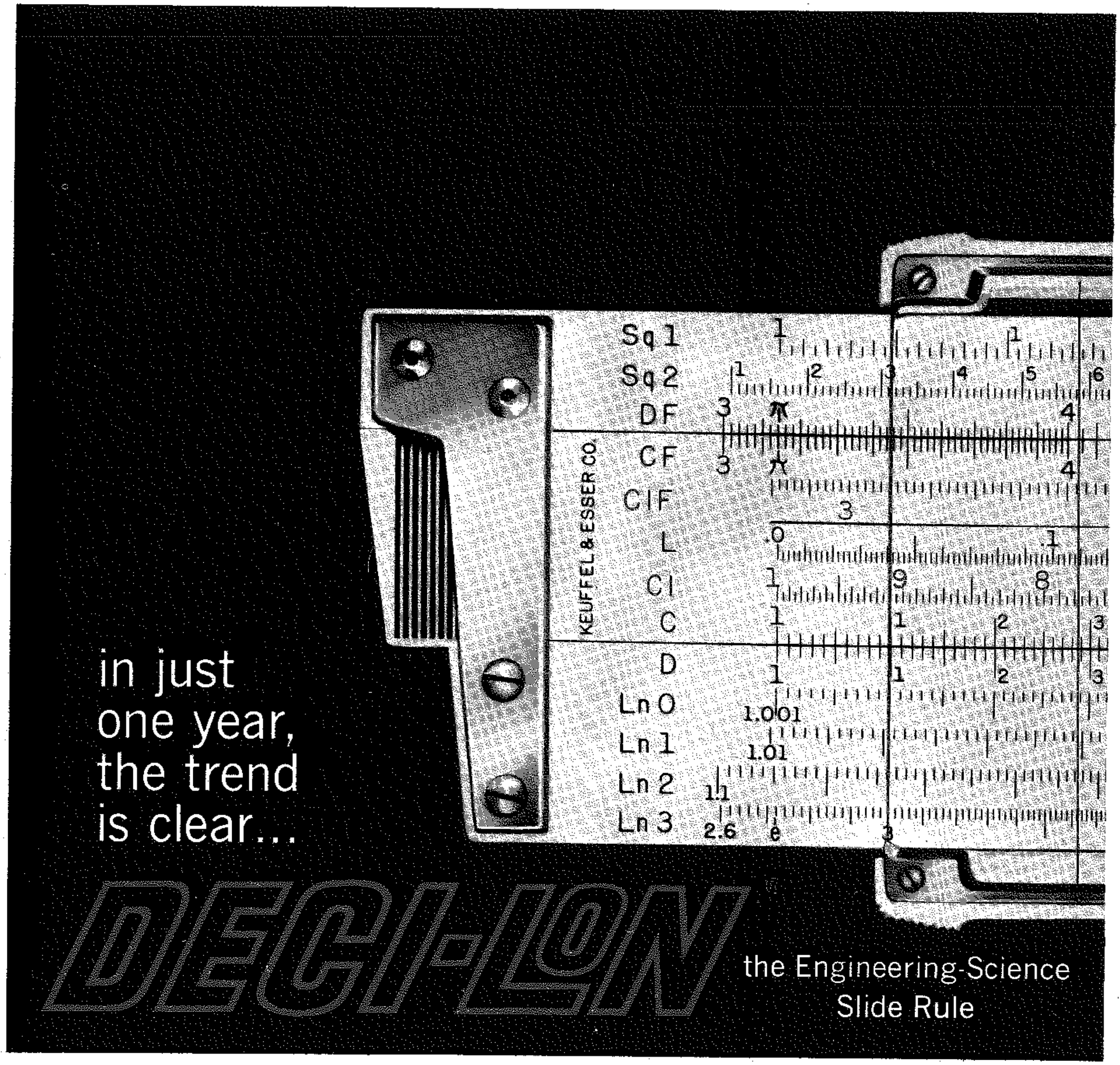

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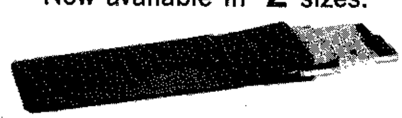

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EDITORIAL

EDITORIAL Fall 1963

For some years there has been a trading of stories about researchers and developers or the R and the D. The way the engineers tell the story, if the rocket is successful, the R's get the praise and IF the rocket is unsuccessful, the D's get the blame. Praiseworthy or not, the successful engineering of our space projects depend on an effective use of graphics in design and communication of workable ideas and inventions.

The economic value of graphical representation in the development of modern research is estimated at about 10% of the dollars spent. For efficient use of our engineering talents in the mammoth projects of the space programs and in the revolution toward automation we should continue to vigorously promote an academic program on an advanced level to teach engineering students graphic design and analysis.

This Journal carries articles on graphics and computers, nomography, graphics curriculum and research in theoretical graphics. For the Journal to continue publishing a significant number of articles we must widen our subscription roles and carry more advertising. A Publication Committee meeting was held at West Point, November 19 with Profs. Blade, Griswold, Hammond, Mochel, Rogers and Wellman present. We discussed the financial problems of the Journal. We unanimously agreed the Journal should continue to serve its widespread leaders in education and industry and we pledged to devote more effort in supporting the Journal. Each of you can help. Please enlist more subscribers and advertisers.

Sincerely,

Mary Blade

Mary Blade

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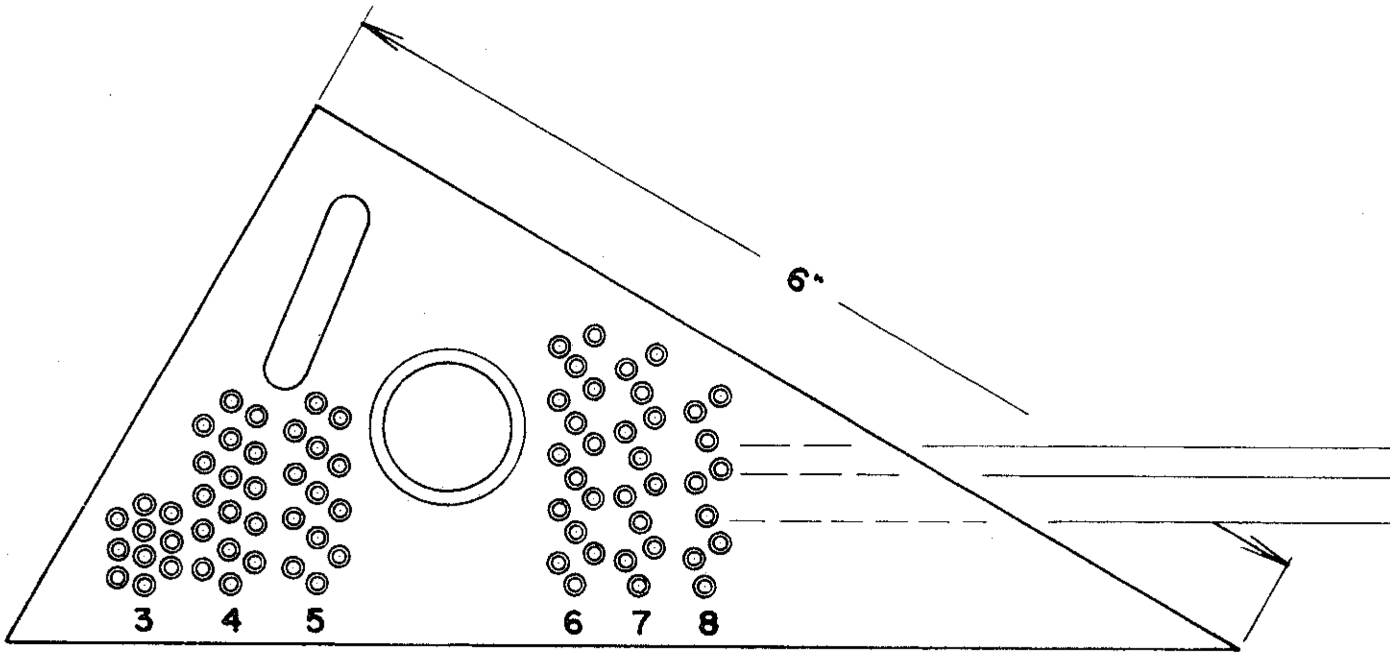

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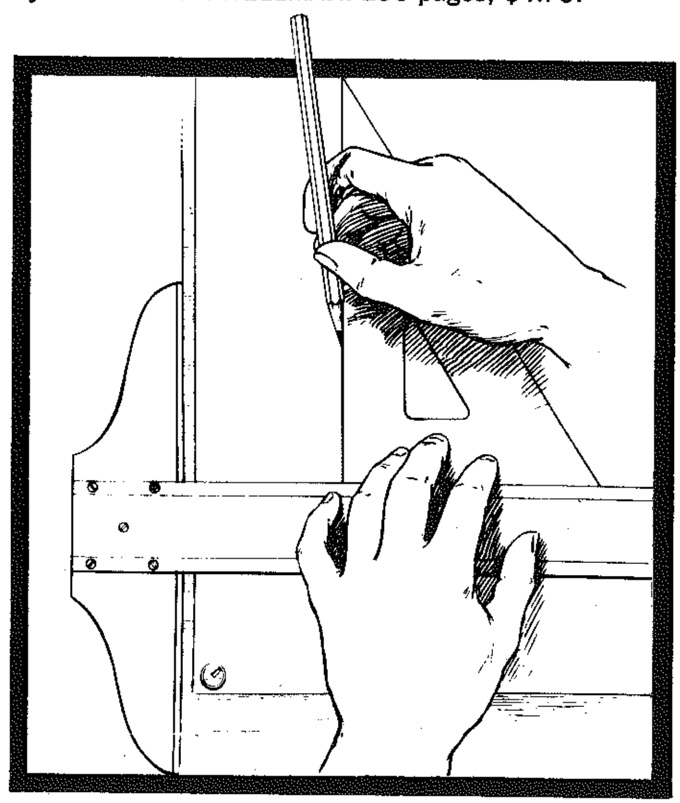

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PROYECCIONES ACOTADAS - INDEXED PROJECTION

By Baruch Bergthal

(Translation by Irwin Wladaver)

[Translator's foreword:

Dr. Bergthal, formerly of the University of Córdova, Argentina, now retired, visited me at NYU to talk about his proposed new descriptive geometry textbook to be written in Spanish, of course. His enthusiasm about the system of descriptive geometry called "proyecciones acotadas" was contagious. I had never heard of "indexed projection" (Dr. Bergthal's preference in English) and it seemed very interesting. I suggested that he write up a couple of examples and that I would translate the article into English and submit it to the JOURNAL.

The system which we are calling indexed projection is not new. In French textbooks it is known as "géométrie cotée," and the one I have devotes about a third of its pages to it. In a Spanish textbook used currently in Mexico at least, the first third of the book is on "proyecciones acotadas." But the system is virtually unknown, I believe, in the United States. If so, then I think it is worth while to introduce it in our JOURNAL. At the same time, I thank Dr. Bergthal for bringing it to my attention with vigor and conviction and for doing the promised exposition.

Two words need careful attention, "cota" and "graduación." "Cota" is defined as a number that corresponds to the distance from a plane. If the plane is horizontal, naturally the cota of a point gives its elevation; but as I understand it, this need not always be the situation. Let's accept cota as an English word meaning distance from a horizontal plane with full interpretation dependent on the context.

"Graduación" translates as graduation. Graduations should be taken to mean the regular divisions of or on a projected line.

Dr. Bergthal's article follows. Traductor es traidor: a translator is a traitor. I hope I have not failed entirely.

I. W.]

Indexed projection is easier than projection in the Mongean system, simpler and equally precise. Operations can be performed in the same way as in Mongean: rotation, auxiliary views, revolution, sections, shades and shadows, and so on.

Indexed projection does not differ much from Mongean. Its characteristic is <u>a single view</u>, for example, a projection on a horizontal plane; and instead of a vertical projection or view, numbers called "cotas" are super-scripted to give the relative elevations of points. These numbers are the distances of points from the basic horizontal plane of projection, a plane to which the basic horizontal plane of projection, a plane to which cota-zero is assigned. Points above the plane are positive, below negative. And so a point in space is located by its projection and its cota.

If we imagine space divided by horizontal planes one meter apart, any straight line pierces these planes in distinct points. The projection of these points on the horizontal plane of projection determines the line by means of its graduations, that is, the horizontal distances between the points along the line. A vertical line projects as a single point; a horizontal line has only one cota, elevation, marked on it.

A particular plane intersecting the horizontal space planes intersects them in horizontal lines of distinct cotas, elevations. The projection on the plane of projection of these horizontal lines indexed with their respective cotas is the representation of that particular plane. However to represent this plane on the plane of a drawing, it is enough to draw a line perpendicular to the horizontal lines, locating on the perpendicular a cota corresponding to that of each horizontal line. Such a perpendicular is known as the line of maximum inclination. This line may be placed anywhere on the drawing, but the cotas must be in correspondence with those of the horizontal lines of the particular plane in which all these lines lie.

A vertical plane has all its horizontals projected to coincide in a single line, the trace of that plane on the horizontal plane of projection.

Two planes intersect in a line common to both planes. Cotas on such a line are indexed to coincide with the cotas of the intersecting horizontals of both planes. To find the intersection of two given planes all that needs to be done is to draw two pairs of horizontal lines with their respective cotas corresponding in the two planes. Joining the two points thus found gives the required line of intersection of the two planes.

Many planes can be passed through a single line: the horizontals of such planes must pass through corresponding cotas of that line.

To determine the intersection of a line and a plane the procedure, as in Monge, is to pass a plane through the given line; the intersection of the two planes intersects the given line in the required point. Two intersecting lines share the same cota as their common point.

As an example: let it be required to draw through a point a line perpendicular to a given plane:

Given a plane **P** by its line of maximum inclination perpendicular to the horizontal lines 1.50 meters apart in horizontal projection (that is, its graduation) and also given a point M of cota 14.00. See Fig. 1, in which the scale [escala] is 1:100.

Required: to draw from point M a line m perpendicular to plane P and to determine:

1. the intersection K of this line and the plane **P**
2. the graduation of line m, that is, the horizontal distance between two consecutive points on it, and
3. the relation and sense of the graduations of both lines ℓ and m.

If we imagine space divided by horizontal planes one meter apart, any inclined plane cuts these planes in horizontal lines $h_1, h_2, h_3, \cdots, h_{14}$ and so on. These horizontal lines form the plane **P**; and a line ℓ, also in plane **P** but perpendicular to the horizontals, has the same graduations as the horizontals which intersect it. Line ℓ may be located anywhere in the plane.

From point M we draw a line m perpendicular to plane **P**. The perpendicular line m through point M is of course perpendicular to the horizontal lines of plane **P**. The projection of line m appears parallel to the projection of line ℓ.

If through point M we draw a vertical plane π perpendicular to plane **P**, then plane π cuts from plane **P** and a line ℓ' parallel to ℓ. We now rotate plane π on to the horizontal plane of cota-7. The points a and b at cotas 7 and 11 respectively will have the following locations when rotated: point a of cota-7 will stay at the same place; point b of cota-11 will be four meters away from line ℓ', that is, the difference between cotas 11 and 7. This is the procedure for obtaining the rotated line (ℓ').

Next we rotate point M; in the identical way we get its distance from ℓ' as 7 meters, the difference between cota-14 for m and 7 for the selected horizontal plane and for line ℓ'

From (M) rotated we draw a perpendicular to point (K) on (ℓ'); by projecting (K) to ℓ', K

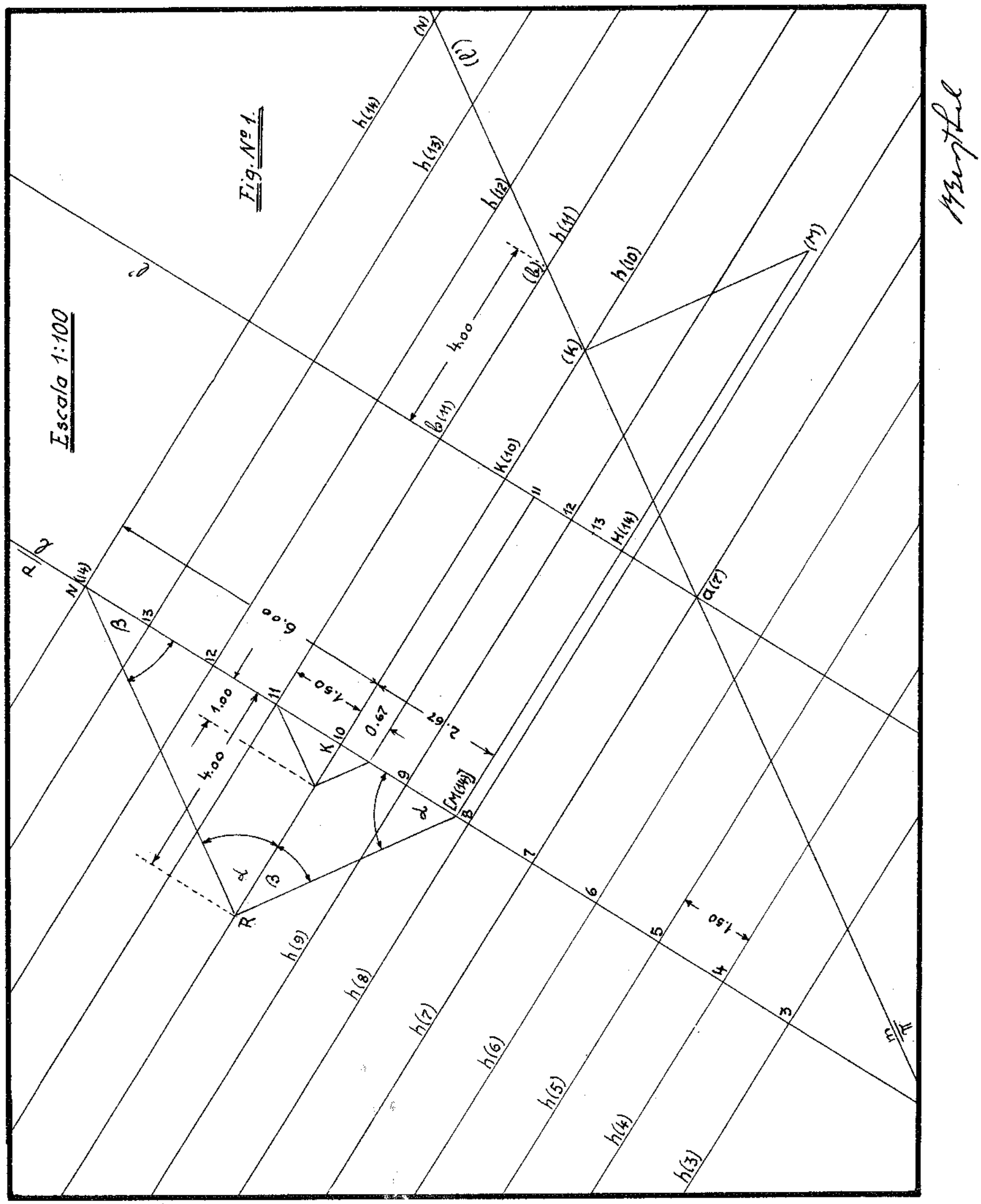

FIG. 1

turns out to be at cota-10, which is a cota common to K, to plane P, and to line m. Between points M and K there is a difference in cotas of four meters; dividing MK into four equal parts we get on MK cotas 11, 12, and 13; and the graduations of line m are in a sense contrary to those of line ℓ.

To find the relation of the graduations of ℓ and m, we determine on ℓ a point N of cota-14 equal to that of point M. We project point M on the vertical plane of line ℓ and we get point [M(14)]. From point K of cota-10 we measure on the horizontal plane of cota-10 four meters (that is, 4 cm., because of the 1:100 scale) and we get point R. Joining point R with points M and N we get a triangle with a right angle at point R.
$\alpha + \beta = 90°$.

The horizontal plane of cota-10 divides the triangle MRN into two similar triangles MRK and NRK.

$$\text{In triangle MRK, } \tan\beta = \frac{MK}{RK}$$

$$\text{In triangle NRK, } \tan\beta = \frac{RK}{NK}$$

from which

$$\frac{MK}{RK} = \frac{RK}{NK}; \quad MK = \frac{\overline{RK}^2}{NK} = \frac{4^2}{6} = \frac{16}{6} = \frac{8}{3} = 2.67$$

Line ℓ has its graduations determined in units of 1.5 for a total of $1.5 \times 4 = 6.00$. To one unit of line ℓ, whose graduation unit is 1.50, there corresponds a unit of 0.67 of line m perpendicular to line ℓ. These two values are reciprocal, since

$$\frac{1}{1.50} = 0.67$$

Summary: Two perpendicular lines have reciprocal graduations and are of opposite sense.

We consider now another problem quite different in character.

Given: four noncoplanar points in space: A, cota-10; B, cota-19; C, cota-14; and D, cota-5, forming a space quadrilateral. See Fig. 2.
Required: to cut lines AB, BC, CD, and DA with a plane such that the section of these lines and the plane is a parallelogram and the perimeter of the parallelogram is 34 meters in length. Scale: 1:100.

The four points A, B, C, and D determine one combination of planes, ABD and CBD, that intersect in line r; another combination, DAC and BAC, intersects in line n. All planes parallel to lines AC and BD cut the space quadrilateral in a parallelogram.

To determine the length of the parallelogram we use the following relationships:

$$AC = n; \quad BD = r; \quad EF = GH = a;$$
$$FG = GH = b; \quad BC = w; \quad BE = p;$$
$$\frac{n}{a} = \frac{w}{p}; \qquad a = \frac{np}{w};$$
$$\frac{r}{b} = \frac{w}{w - p}; \quad b = \frac{r(w - p)}{w}.$$

Since $2a + 2b = 34.00$ meters
$a + b = 17.00$ meters

$$a + b = \frac{np}{w} + \frac{r(w - p)}{w} = \frac{np + rw - pr}{w} = 17$$
$$np + rw - rp = 17w$$
$$np - rp = 17w - rw$$
$$p(n - r) = w(17 - r); \quad p = \frac{w(17 - r)}{n - r}$$

We measure the true lengths of w, n, and r; by rotation: we get w = 9.60 mts.
n = 14.80 mts.
r = 18.40 mts.

The rotation is based on the difference between the cotas of the ends of each line.

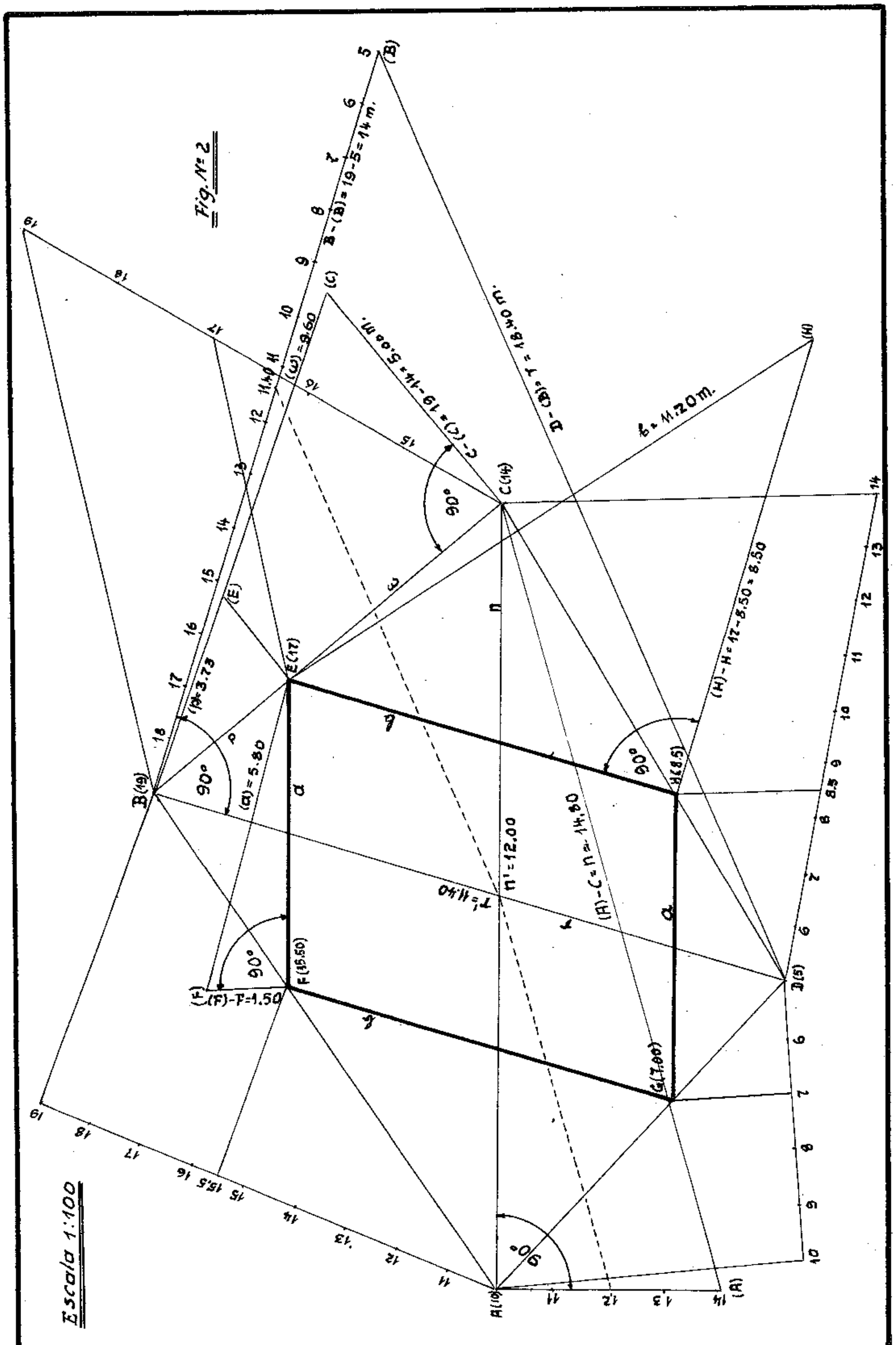
Fig. Nº 2
Escala 1:100
B-(B) = 19-5 = 14 m.
C-(C) = 19-14 = 5.00 m.
D-(D) = T = 18.40 m.
t = 11.20 m.
(H)-H = 17-8.50 = 8.50
(A)-C = n = 14.80
n' = 12.00
T' = 11.40
(F)-F = 1.50
(ω) = 9.60
(α) = 5.80
90°

FIG. 2

$$p = \frac{9.60(17 - 18.40)}{14.80 - 18.40} = 3.73$$

$$a = \frac{pn}{w} = \frac{3.73(14.80)}{9.60} = 5.80$$

$$b = 17.00 - a = 17.00 - 5.80 = 11.20$$

The rotation of the lines EF = a and EH = b verifies these calculations.

To draw the parallelogram EFGH it is sufficient to find only one point, E, and then by drawing parallels to AC and BD we find the required parallelogram.

To determine the cotas of the vertices of the parallelogram do a graphical or a numerical interpolation. The cota of point E suggests the following graphical procedure. From point C draw any line; at any convenient scale, say 1:50, enter cotas on the line from 14, corresponding to point C, to 19, corresponding to point B. Next connect point 19 to point B and then draw from point E a parallel to B-19. Where this parallel intersects line C-19 will be obtained with exactness the required cota, in this case cota-17.

The other cotas corresponding to the points F, G, and H are found in the same way.

Notice that in the parallelogram EFGH the parallels EH and FG have the same difference in their end cotas since

$$15.50 - 7.00 = 17.00 - 8.50 = 8.50 .$$

The same of course happens with the parallels EF and GH:

$$17.00 - 15.50 = 8.50 - 7.00 = 1.50 .$$

Finally, it can be shown that points A, B, C, and D do not belong to the same plane. In the place where the lines r and n apparently intersect in projection, by means of interpolation of cotas the line AC has cota-12 at point n' and the line BD has cota-11.40 at point r', so that r' is therefore below n'. See Fig. 2.

To determine the angles of the parallelogram it is necessary to find the true length of one of its diagonals, in accordance with established procedures.

Continued from page 29

Nominating Committee:
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(From By-Laws of the Division)

A properly prepared petition nominating a member for any office, that bears ten (10) signatures of members of the Division and Society shall require the nominating committee to place the name on the ballot.

The nomination period must be considered as being closed at the end of the last conference session of the mid-winter meeting. A petition for nomination received after the close of the mid-winter meeting cannot be accepted. A conference session is herein defined as a regularly scheduled meeting at which papers are presented for discussion.

NOMINATION FOR DISTINGUISHED SERVICE AWARD

Any member of the Division who would like to nominate a candidate for the Distinguished Service Award is invited to send the name of his candidate to any of the members of the Committee on Special Awards. It isn't necessary to start a campaign before the election; just write to any committeeman whose name is appended below.

Anyone who would like to be considered by the Committee on Nominations for some office of the Division may send his own name to any member of the Nominating Committee for consideration.

Both Committees consist of:

Edward M. Griswold
Matthew McNeary
Irwin Wladaver, Chairman

Announcement

Descriptive Geometry Award

The Committee for Descriptive Geometry Award of the Engineering Graphics Division is pleased to announce that the Gramercy Guild Group, Inc., has again offered to provide $100 for an award in the Descriptive Geometry competition. The Committee has established the following rules for eligibility:

1. An article involving descriptive geometry in the solution of a problem or an article on descriptive geometry may compete.

2. The article must have been published in a periodical.

3. The article must have appeared in an issue between the dates of January 1963 and December 1963 inclusive.

4. Descriptive Geometry must be the primary interest of the article.

5. The article must be brought to the attention of the Committee. The Committee will naturally search diligently for all such articles but is not responsible for finding all such articles.

6. The article will be judged on originality, resourcefulness, and effectiveness. The drafting and the use of drafting aids, etc., should be competent, but are secondary considerations.

7. A majority of the committee votes received will determine the winner.

8. The winner will be announced at the Annual Dinner meeting in June and the award will be made at that time.

The Committee is undertaking a search of the periodical literature and as this is an extensive job any suggestions of suitable articles or references will be greatly appreciated.

Kindly send any information regarding possible articles to any one of the Committee members.

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THE PLACE OF THE DIGITAL COMPUTER IN GRAPHICS INSTRUCTION AND THE PURPOSE OF FLOW DIAGRAMS

Given at the Engineering Graphics workshop in conjunction with the 1962 ASEE meeting at the Air Force Academy. Charles J. Baer, University of Kansas.

The bulk of this morning's instruction and work has involved the analog computer. I have been asked to discuss the digital computer. In order to show how the digital computer fits into the picture, I will divide this discussion into three parts, to wit:

1. A comparison of analog and digital computers.

2. How the subject of digital computer programming can be fitted into a graphics course.

3. Flow diagrams, why they are used and what some typical flow diagrams look like.

To commence the first of these three, we can say that a mechanical system consisting of masses, springs, and dampers can be represented in terms of an electrical analog (analogy) made up of capacitors, inductors and resistors. If such an elctrical analog is constructed physically and the performance is measured as a means of studying the original mechanical system, then analog computation is being used. Instead of simulating a given system with an element-for-element analogy, an analog computer generally simulates a set of equations with an assemblage of physical devices that carry out simultaneously the various mathematical operations specified in a set of equations. Such a computer can handle differential as well as algebraic equations; in so doing it provides continuous integration and differentation of the variables as required. So much for the analog computer.

Digital computers are essentially arithmetic counting machines that solve mathematical problems largely by employing a simple step-by-step process of counting. By performing these counting (and associated) operations at enormously high speeds they make it possible to employ various approximation procedures involving a high degree of iteration. These operations are performed by providing a program of instruction in which the operations are broken down into a series of additions, subtractions and other similar operations. This lends itself to extended approximation procedures from which any number of significant figures is attainable. Whereas the results of an analog computer's output are frequently read on a meter or oscilloscope, or displayed in graphical form, the results of a digital computer's computation are usually printed on a sheet of paper in several columns of figures carried to 8 or 10 significant figures. In other words the output of digital computers is oftem much more accurate than that of analog computers.

Another difference between the two types of computers has been in the matter of memory or storage. It is possible, and customary, to store written programs, subroutines, and great quantities of data in the memory unit of a digital computer. It has not been possible to do this in most analog computers.

However, some of the differences between the two types of computers have disappeared, or at least diminished, when some recently-designed computers are compared. In one analog computer a high-speed memory unit has been installed and successfully operated. It is--or soon will be--possible to procure hardware for a new analog computer that will print out the answers in digital arrangement similar to the output of a digital computer.

Conversely, it is now possible to buy hardware for a digital computer that will enable the answers to be printed in graphical form. In fact, the automatic drafting machine operates as part of a digital computer package.

In summary, then we can say that an analog computer is less accurate than a digital computer but easier to program: it can perform differentiation as well as integration, but is not as useful as its digital counterpart for processing large volumes of data. The ordigital computer is more accurate and at the same time more difficult to program. It can perform integration, but not differentiation, and is quite capable of processing large amounts of data.

Now, for the aspect of teaching digital computer programming in engineering graphics classes. Why are we doing it? We are doing it primarily because we were asked to do it by our largest degree-granting department. This is a department whose curriculum is bursting at the seams and which feels that there is not enough room or time for a computer course. Therefore, we began to offer in 1960 about 5 contact hours of computer instruction to all students in the second of our two integrated graphics courses. Since that time we have found if necessary, in order to do a decent job, to increase this class-time to about seven hours. Outside reading and time spent programming a simple problem amount to another three to five hours.

Other reasons for offering this instruction are: (1) a chance to move into a rather new field, (2) a chance to upgrade ourselves as professionals, a chance to show that some graphical or semi-graphical problems can be solved on the digital computers, and (3) an opportunity to get some interesting material into the curriculum during the freshman year. (We are losing freshman engineers at an alarming rate, and feel that this introduction to computers will help to make the freshman year a little more attractive.)

How can digital computer instruction be fitted into a graphics course? At first it will have to be treated as a separate subject. The characteristics and peculiarities of one (or several) computer(s) will have to be discussed. The language of the computer to be used must be explained. Then a simple (A+B)/C type of problem will help to tie things together and will prepare students to understand just how a program is written. Also, during this introductory phase of the subject, the computer flo diagram can be (and should be) introduced and explained. The flow diagram is a graphical device which most experts agree is necessary for the proper planning and trouble-shooting of a program. A flow diagram also makes it easier for an instructor to explain an example program to a class. After a sample program or two and flow charting have been presented to a class, example problems involving graphical situations can be presented. Now, the students can follow reasonally well programs for the Method of Least Squares, the Method of Averages, Simpson's Rule, and the Trapezoidal Method for obtaining the area under a curve. These are not the only graphical type of problem that can be put on a digital computer. But they are the type of graphics problems we happen to be offering in this particular course at this time. Thus, we feel that computer instruction ties in nicely with graphics at our school.

Now, let us take a look at flow diagrams You have seen the flow diagrams for the analog problem worked in class. This type of diagram is considerably different than the type used for digital computers. FIG. 1 shows the analog flow diagram. Here you see combinations of integrators patched to solve a double integration problem. If you look closely and think back to this morning's problem, you can visualize, at least in part, the electrical simulation of the problem.

The next FIG. (FIG. 2) shows the typical components of flow diagrams for digital computer programming. Two styles are in wide use today. That on the left was developed by persons using punched-card machines. Because punched cards are synonymous (but not exclusively so) with IBM equipment, and because IBM has sold more than 50% of the computers in use so far, it goes without saying that many programmers use style A. However, style B has been adopted by a national organization of computer operators, and thus also is being used extensively. (Note R:0, a "logic" step, means: "Is R equal to zero?" This will be explained on the next slide.)

FIGURE 3 shows a flow diagram using style A for Cramer's Rule which is used to solve two or three simultaneous equations using determinants. This diagram is essentially left to right in flow.

Note the branching, or logic, step: Z:0.

If Z is any value except zero, we move along to the main argument, get the answer, punch it, and return for another set of variables. But if Z should happen to equal zero, we take the upper path and punch out a bunch of zeros (or the word ZERO) to indicate that Z is zero. This program is designed to solve two simultaneous equations for many values of a, b, c, d. It goes around and around until all the initial pieces of data have been processed.

Figure 4 • presents a diagram using style B for a simple program in which we add 800 numbers starting with 1, 2, and so on. This shows an initializing block, the argument (function) block, two incrementing blocks, and so on. Both figures 3 and 4 illustrate two important points about flow diagrams.

1. Diagrams written in this general algebraic form will work for any digital computer.

2. Diagrams can be as general or as complicated as the programmer wishes.

Both of these example diagrams are fairly general. For instance, the initializing block contains 3 elements. We could have made a separate block for each of these steps had we wanted to. Conversely we could have combined the two incrementing steps into one block. Whether several steps are combined into one block or not is up to the programmer.

Figure 5 shows a somewhat different type of diagram. This is definitely a step-by-step diagram. Only part of the diagram is shown. This diagram differs from the previous two in that it starts at the upper left, goes down, then up, and so on. And it also can be used for only one particular computer, the Royal McBee LGP 30. This is because it is written in machine language, rather than in general algebraic terms of the type shown in the preceding two diagrams. This flow diagram is too detailed to give a good overall picture of the problem but would be very helpful in debugging a program if trouble develops. In writing a program in machine language, some programmers might make two diagrams, one of a rather general nature defining the problems, and another of a detailed step-by-step type. As computers become more sophisticated, they will use a language that is more nearly like our own written English and mathematical language, and we will use less and less of the machine language typified by this problem.

I hope that you have been able to see the importance of the flow diagram in computer programming, today. These diagrams are very helpful, if not necessary, adjuncts to programming both analog and digital computers.

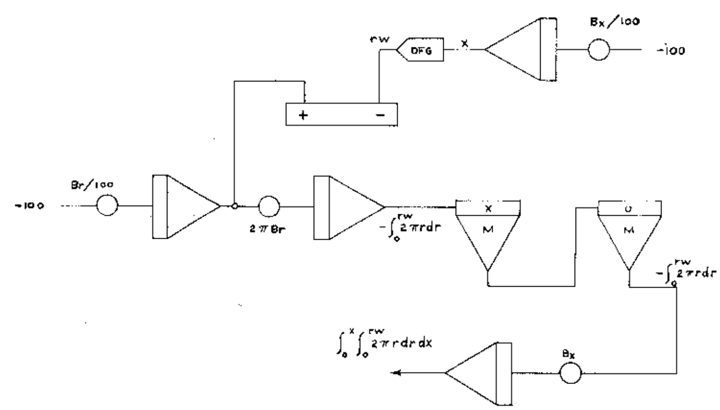
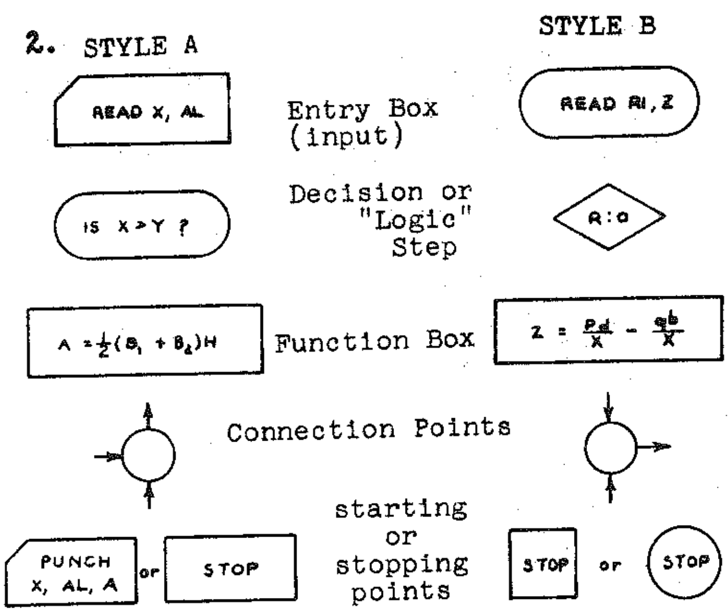


FIGURE 1
Volume of object with varying radius and length.

2.



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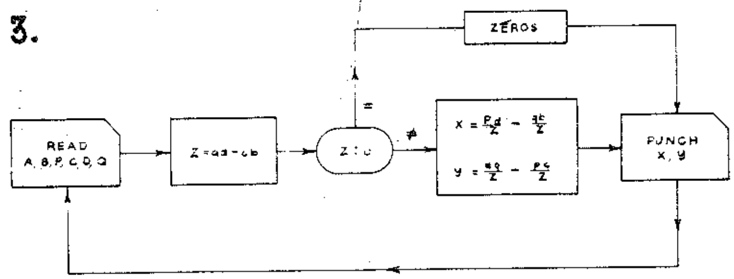


FIGURE 2 - Block outlines for various types of programming operations for two different styles.

FIGURE 3 - Flow diagram for computer program for Cramer's Rule.

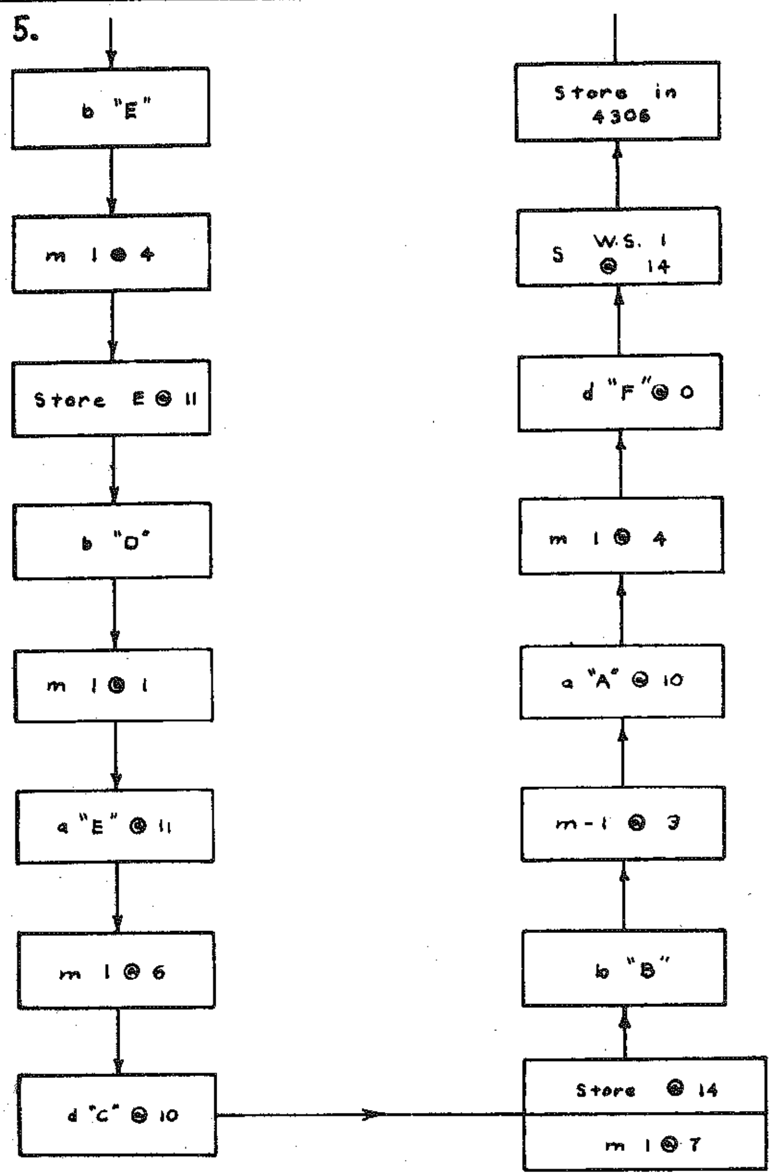
FIGURE 4 - Flow diagram for computer program for adding 800 numbers.

FIGURE 5 - Flow diagram for

$$K = \frac{C\ (A+B)\ -F(D+E)}{CF}$$

for the LGP-30 computer.

5.



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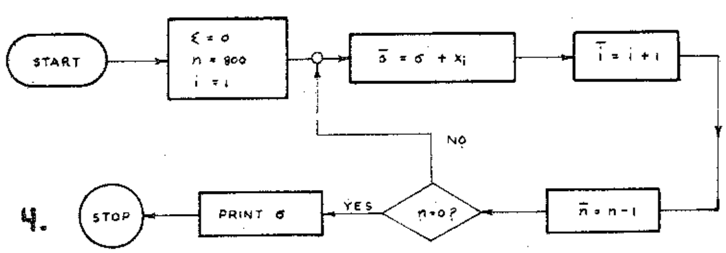

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ENGINEERING GRAPHICS- GENESIS TO ENGINEERING DEVELOPMENT

Earl D. Black
Senior Instructional Specialist
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General Motors Institute

Today, we are often jarred into frustation by those who expostulate with, "Let us educate (teach, train, develop) the student of engineering with the knowledge that he will need - say five, ten, or more years from now." This challenge starts a chain reaction of conversation and soon some brave soul asks: "Precisely, what will the engineering student need by that time?" Thus, the conference turns into a long and pointless tirade by some individual who begins to sound like a prophet.

About the only obvious fact is that the engineer of the future will need two eyes with which to see, two ears with which to hear, two hands and two feet that move, a nose with which to smell, a body that holds himself together, a mouth that talks, and the development of his mental faculties through acquisition of usable knowledge and experience.

Someone may suggest that the engineering student should be required to learn the basic fundamentals of his chosen field. But then the argument continues into the wee hours of the morning with various members of the conference debating fundamental principles versus specialization and obsolescence. The group then retires confused, befuddled, and unsatisfied, having arrived at no absolute solution to the question as to the scope of fundamentals required for a given curriculum.

One may rightly call attention to the fact that curriculum construction is only part of the problem. What about the selection of students who are interested in becoming an engineer, as well as students who have the required elementary and high school background, and who have the ability to learn? And how about a dedicated and competent faculty?

COURSE AND TEACHING OBJECTIVES

I was once asked to formulate departmental objectives for engineering graphics. The result is quoted below for examination:

> "To develop a dedicated faculty who have attained recognized ability in graphical communication and engineering design dealing with both established and new developments in engineering science and technology."

A few months later the request was to provide a statement of general objectives for engineering graphics. Objectives submitted:

> "Engineering graphics should develop the engineering student's ability to use sound judgment, to appreciate the importance of aesthetics, to communicate ideas clearly and accurately, and develop his creative talents by improved analysis and synthesis with the methodology involved in performing the design function of engineering."

The critical problem is twofold. First, how can these objectives be successfully achieved in the alloted time for this part of the undergraduate curriculum? Second, how can we recognize and isolate the required fundamental items of knowledge into logical and progressively related units of instruction?

Scientific discoveries become useful only when they are applied to machines, vehicles, processes, and products wanted by mankind. Industry in general is more interested in graduates who are well qualified in fundamentals rather than descriptive courses. To assure increasing and effective individual performance, we must find that formula which includes the knowledge that best fits the engineer for performance of his job responsibilities. The student must develop as an individual, as a member of a team group, and as a desirable citizen in his community.

In engineering graphics the student should develop his ability to communicate specifically and accurately in graphical form. The student should be initiated into elements of design and design analysis. He should learn to recognize the value of working drawings. He should understand the theory of orthographic projection principles and be able to use layouts as a basis for developing design ideas to useful function.

A basic course in engineering graphics will fall short if it does not include practice in making sketches, freehand and semi-freehand drawings, and pictorial drawings as a means of accurately communicating engineering intent. The student should be taught the proper use of adequate dimensioning systems and how to express specifications and instructional notes required for fabrication. He should be able to formulate technical directions in simple, precise, and clearly understandable terms.

Engineering graphics should help the student acquire an attitude of critical analysis and constructive thinking in solving progressively difficult problems in design. The student should be encouraged to acquire basic principles required for pursuing later studies in engineering science which require graphical communication.

The student should learn how to combine graphical and mathematical methods in solving design problems common to science and engineering. He should develop an ability to visualize and anticipate future difficulties in construction, assembly, marketing, and servicing of products by analysis of component parts. He should learn how to avoid the pitfalls of under or over design. He should acquire some skill in applying graphical methods in analyzing space concepts and solving problems typical of associated courses in the engineering curriculum.

HELPING THE STUDENT LEARN JOB REQUIREMENTS

Courses in engineering graphics should be so designed as to help the student meet job responsibilities. The teacher should guide the student in acquiring personal qualifications compatible with the job. The student must learn to exercise sound judgment in his relationship with his fellow workmen.

- He should learn to respect authority.
- He should have good health - and especially good vision.
- He should be willing to work and recognize that work is the source of material growth and spiritual fulfillment. He should be encouraged to have an ambition for the job; he should be interested in becoming the best engineer that his personal qualifications will permit.
- He should be encouraged to set an attainable goal for himself and to have a program for self-development.
- He should be able to think constructively, plan ahead, and organize work procedures.
- He should have self-initiative but he should be able to follow instructions.
- He should be able to effectively use oral, written, and graphical communication and recognize the advantages of each with proper integration of their uses.

Some colleges and universities give standardized tests which assist in determining student deficiencies. Personal interviews, group conferences, and comprehensive tests are likely to reveal probable reactions of the student to work situations. A record of his past performance, scholarship, personal attainments and character references from teachers, supervisors, and landlady undoubtedly will give some indication of the student's probable success as an engineer. The teacher should assist the student in job qualification rather than having him become a job misfit.

FRONTIER AREAS

Let us examine a few frontier areas of engineering science which are based on today's technology. Many phases of engineering technology are fast becoming obsolete to the extent that the student is being asked to forget some of the items learned as a sopomore by the time he has become a senior.

Direct energy and energy conversion processes are taking the place of mechanical fabrication methods. The number of processes available to do a specific job, and the number of basic scientific principles being introduced into manufacturing include deep-rooted changes in application of the fundamental sciences.

Present-day computer methods permit the coordination of entire manufacturing systems. The student is expected to know about new materials and materials handling. There is a complete broadening of the scope of required knowledge for today's practicing engineer.

It has become increasingly important for the engineering teacher to help his students set a pattern of continued learning after graduation in order to meet the challenge of the ever changing technology.

The competitive world economy demands that we excell in the quality of our technological manpower and improved industrial systems. The growing scientific knowledge is constantly changing our environmental relationship as to time, position in the universe, and speed with which we must get things done. It is important that we improve the liaison between engineering educators and industrial management. We dare not make an error in our choice of knowledgable facts and methods of procedures if we expect to keep abreast with other professions in this space age.

THE TEACHING FACULTY

Effective teaching requires careful planning and properly prepared teachers who know "how to get things across" to others. The teacher's job is primarily getting the student to acquire specific knowledge and develop an ability to make necessary applications common to the profession.

Members of the faculty, who teach engineering graphics courses, should be familiar with the various classifications of the engineering profession. They should be well grounded in physics and mathematics. They should understand the psychology of human behavior. The teacher should also be proficient in the use of his native language. He should set his students a good example by using good oral and written language as well as proper integration of their use with graphical communication.

The better teacher carefully inspects his own effectiveness and adjusts his approach to unexpected requirements of the teaching situation. He thoroughly and correctly analyzes the instructional coverage in terms of basic items of knowledge which must be "put across." He coordinates the timing of the current units to be taught with what has been taught as well as with what is yet to be taught. He thoroughly prepares the lesson to be taught before he begins the presentation. He places the student in a trial situation and inspects the student's ability to make desired applications of knowledgable facts and scientific principles. During the instructional process the teacher should make adjustments in the rhythm of instruction to individual differences of students.

The attitude of both the teacher and the student is very important. Both must be interested to achieve effective learning on the part of the student. The student must have a chance to participate to achieve lasting knowledge. He must want to learn. Often the teacher of engineering graphics has the best opportunity to activate and develop the student's interest and inspire in him a growing desire to learn the broader application of engineering.

GRAPHICS TANTILIZER

Contributed by Ernest R. Weidhaas, Associate Professor in charge, Engineering Graphics, Pennsylvania State University

A materials conveyor cart 3' wide x 6' long runs in a tunnel housing with vertical walls 5' apart.

What is the sharpest 90° turn that may be specified allowing a minimum clearance of 6" between cart and wall?

Elementary Nomography

J. Norman Arnold, Professor of Engineering Graphics
Purdue University

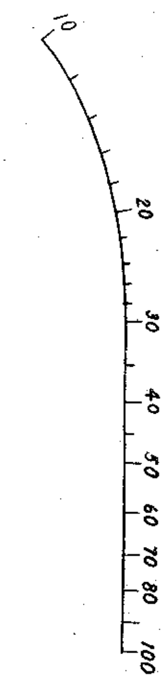
INTRODUCTION

This written report attempts to set down the content of the session on Elementary Nomography as carried out during the summer school of the Division of Engineering Graphics held at the Air Force Academy in June 1962. The actual summer school session permitted: step-by-step development of definitions and theory, the working of an example, discussion of alternate methods at certain points, followed by the solution of a problem by the participants. Each participant was aided, as necessary, in his solution of the problem before proceeding to the next topic.

Publication is a more restrictive form of presentation. The reader cannot as readily ask questions, for example. Also, he is very unlikely to interrupt his reading to solve a problem at the time which might be most helpful to his understanding.

FUNCTIONAL SCALE

The fundamental element of a nomogram is a graduated scale; it may be straight or curved, include a zero value or not, be uniformly graduated or non-uniform in nature. The designer of a nomogram often has some choice in the type of scale he selects, but his choice cannot be entirely arbitrary. The choice is dependent upon the mathematical, or functional, relationship between the quantities represented. Logarithmic scales, such as found on slide rules, often are appropriate elements of nomograms.



An example of a functional scale is shown in Fig. 1; it is curved, non-uniform, and does not extend to zero. It should be noted that the graduation strokes for the scale are made perpendicular to the curve tangent; number-bearing strokes (and like ones not numbered) are longer; the graduation basis is changed only at a number, never between numbers (see 50, for example). Numbers are not placed at all long graduations, particularly if they would be crowded.

The proportions of such a scale often may be enlarged to permit more accurate reading, or the proportions may need to be reduced in order that the scale may fit in a limited space. The factor of proportion is called modulus.[1]

The example in the next section should aid in demonstrating the usefulness of functional scales and in explaining the meaning of the term modulus.

ADJACENT FUNCTIONAL SCALES

A mathematical relationship between two variables, u and v, expressed generally as

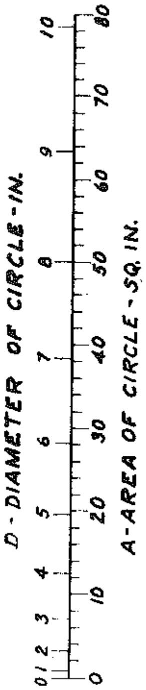
$$f_1(v) = f_2(u) \qquad (1)$$

can be represented by a graduated scale having values of u marked on one side of a line, and a scale for v on the other side. The necessary condition which must be fulfilled by the nomogram is that the same functional modulus (or scale factor) is used for each scale -- the one for u and the one for v.

EXAMPLE As an example, the equation for area of a circle

$$A = (\pi/4)\, D^2 \qquad (2)$$

is shown in adjacent scale form in Fig. 2, which has a uniform A-scale. In the original drawing the functional modulus of the A-scale was selected as 0.1 in., making the length of the scale from 0 to 80 just 8.0 in., since 0.1x80 = 8.0. Distances on the D-scale were constructed with the same functional modulus of 0.1 in. For integral values of D, the distances on the original drawing must be $0.1(\pi/4)$, or 0.07854, multiplied by the squares of D, which are: 1, 4, 9, 16, 25, 36, 49, 64, 81, and 100. From the 0 to the 10 of D is then 7.854 in. Additional computation and measurement, or sometimes graphical interpolation, are necessary to locate intermediate graduations.



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A constant multiplier times the functional modulus is called scale modulus. In this example the scale modulus for the D-scale is $0.1(\pi/4)$, or 0.07854.

PROBLEM The D-scale in the foregoing example is non-uniform and difficult to read accurately at the low-number end. If the equation were written $D = \sqrt{(4/\pi)A}$ a uniform D-scale would result, and the A-scale would be non-uniform, and compressed at the high-number end. A compromise form results if the equation is written

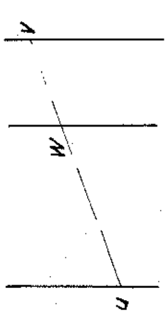
$$(A)^{2/3} = (\pi/4)^{2/3}(D)^{4/3} = 0.85(D)^{4/3}$$

Prepare an adjacent scale nomogram for the equation in this form. Values of A of 0, 5, 10, ···80 when raised to the 2/3 power are approximately as follows: 0, 2.93, 4.65, 6.09, 7.37, 8.55, 9.66, 10.7, 11.7, 12.6, 13.6, 14.5, 15.3, 16.2, 17.0, 17.8, 18.6. For values of D of 0, 1, 2,···10 the corresponding values of $0.85(D)^{4/3}$ are: 0, 0.85, 2.14, 3.68, 5.40, 7.27, 9.26, 11.4, 13.6, 15.9, 18.3. The reader will find that a functional modulus of 0.5 in. (or the 20-scale on the engineers scale) will result in a scale length slightly greater than 9 in.

PARALLEL SCALE NOMOGRAM

The type of equation which may be represented in nomogram with three parallel scales is

$$f_1(u) + f_2(v) = f_3(w) \qquad (3)$$



3

and in diagram form, Fig. 3, the nomogram is used by laying a straight edge across the three scales, perhaps through a known value of u and a known value of v, and reading the corresponding value of w. If u and w happen to be known quantities, or if v and w are the known quantities, the straight line will locate corresponding values of v or of u to satisfy Eq. (3).

From proportions in similar triangles of Fig. 4 it can be determined that the functional moduli of the several scales and the spacing of scales must be related as follows.[2]

$$a/b = m_u/m_v \qquad (4)$$

and

$$1/m_w = 1/m_u + 1/m_v \qquad (5)$$

Another form of Eq. (5) that is sometimes useful is

$$m_w = (m_u m_v)/(m_u + m_v)$$

EXAMPLE The area of material cross-section for a hollow tube is given by

$$S = (\pi/4)\ (D^2 - d^2) \qquad (6)$$

where D is outside diameter and d is inside diameter. For a range of values of D from 0 to 10 in. and d from 0 to 8 in. design a parallel scale alignment chart to solve Eq. (6).

The equation as given has a minus sign. If the D and d scales are to be the outside ones the direction of increasing values for d would be opposite to S and D. All positive signs would result and all scales would increase in the sme direction if the equation is written

$$d^2 + 4S/\pi = D^2$$

If a functional modulus of 1/6 in. is selected for the d-scale, its length would be 10.67 in. The scales will be equally spaced if the same modulus of 1/6 in. is used for the S-scale. Plotting the scales with a modulus of 1/6 in. is made easy by the 60-scale. The squares of d of 0, 1, 4, 9, 16, 25, 36, 49, and 64 are computed first, then these distances are laid off with the 60-scale, choosing 6 units for 1 in. Each inch on the architect's 1" = 1'-0" scale corresponds to 1/12 in. and facilitates plotting the S-scale. However, the value of S must be multiplied by $4/\pi$, or 1.27. This can be done graphically using a diagonal line and parallels, or it can be done numerically.

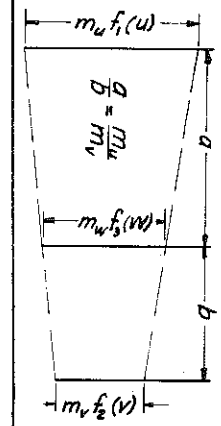
Principal graduations only are included on Fig. 5 for this example. Fuller graduation would generally be preferred; graphical interpolation or additional numerical computations can be used to locate additional graduations.

PROBLEM For 1962 and for a number of earlier years the U.S. federal income tax on the basis of the standard deduction, for the lowest tax bracket, has been computed from

$$T = 0.2(0.9S - 600E) = 0.18S - 120E \qquad (7)$$

For a married taxpayer Eq. (7) holds for S up to \$10,000 and up to a tax, T, of \$1600; for S greater than \$10,000 the equation is modified to

$$T = 0.2(S - 1000 - 600E) = 0.2S - 200 - 120E \qquad (8)$$



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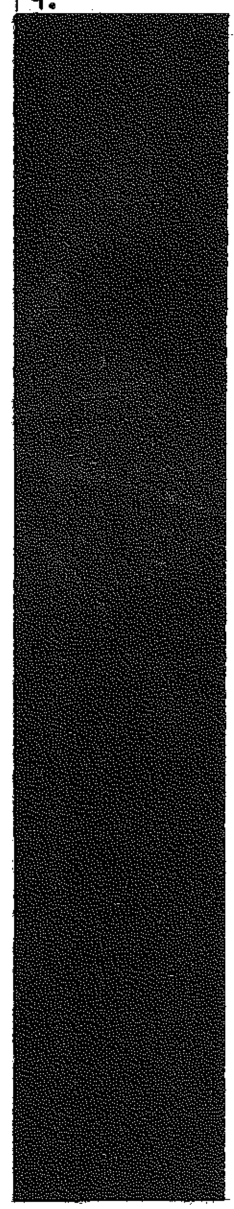
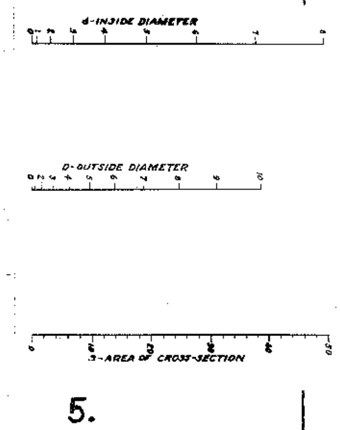




Again, this form of equation applies up to T of \$1600. The quantity, E, is number of exemptions, and is an integer. If the taxpayer or spouse is over 65 years of age, E is increased; if either is blind, it is increased. Each dependent increases E by one. Prepare a parallel scale nomogram for Eq. (7) and (8) for E from 2 to 8, and for gross income, S, up to \$14,000.

The scales of this nomogram will all be uniform. The coefficients 0.18, 0.2, and 120 provide a puzzling feature for the beginner in nomography, but, this is a good problem for clarifying the effect of multiplying constants.

One solution, in outline only, is indicated in Fig. 6. This is based upon the term for E being transposed so that

$$T + 120E = 0.18S \qquad (S\text{:up to } 10{,}000)$$

$$T + 120E = 0.2S - 200 \qquad (S\text{:}10{,}000 +)$$

Folded scales for S and for T would permit larger moduli to be used for the same space requirements, and would provide slightly greater accuracy. The T-scale might range from 0 to 1000 on one side of the line, and the opposite side of the line might carry T from 600 to 1600. An associated folded S-scale would be required ranging up to 10,000 on one side of the line and from 4,000 to 14,000 on the opposite of the line. On the T-scale the same graduations could serve for both ranges of the scale. This is not true for S. In part of its range the function is 0.18S; in another part it is 0.2S - 200. A diagram of this nomogram is shown in Fig. 7.

PARALLEL SCALE NOMOGRAM (PRODUCTS OR QUOTIENTS)

Products or quotients of variables, even raised to constant powers, can be put in the form of Eq. (3) by taking logarithms.[3]

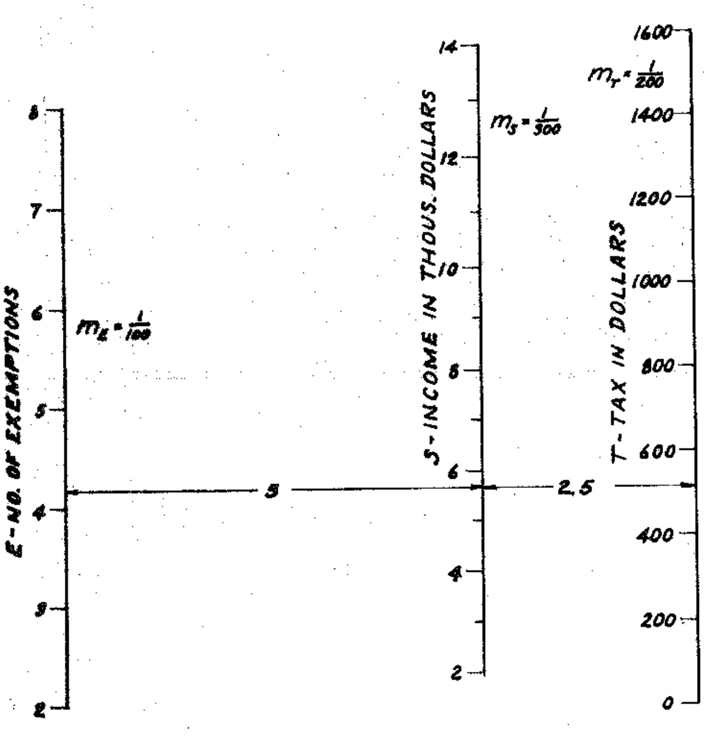
EXAMPLE The volume of a cylindrical tank, for example is

$$V = (\pi/4)\, D^2\, H \qquad (9)$$

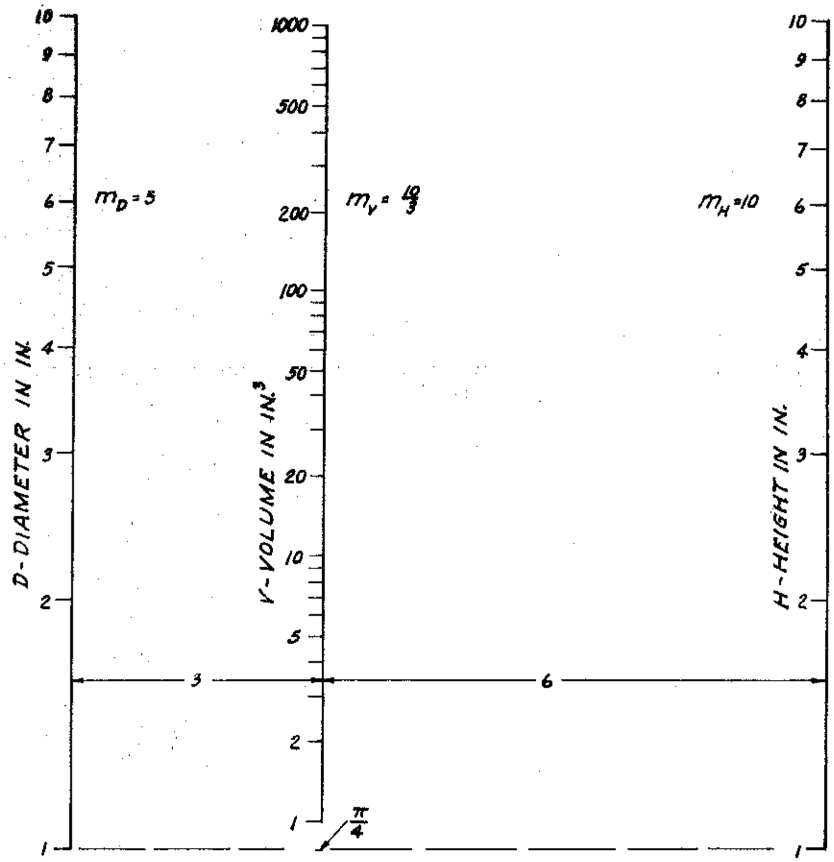
where D is diameter in ft, H is height in ft, and V is volume in cu ft. In log form

$$\log V = \log(\pi/4) + 2 \log D + \log H$$

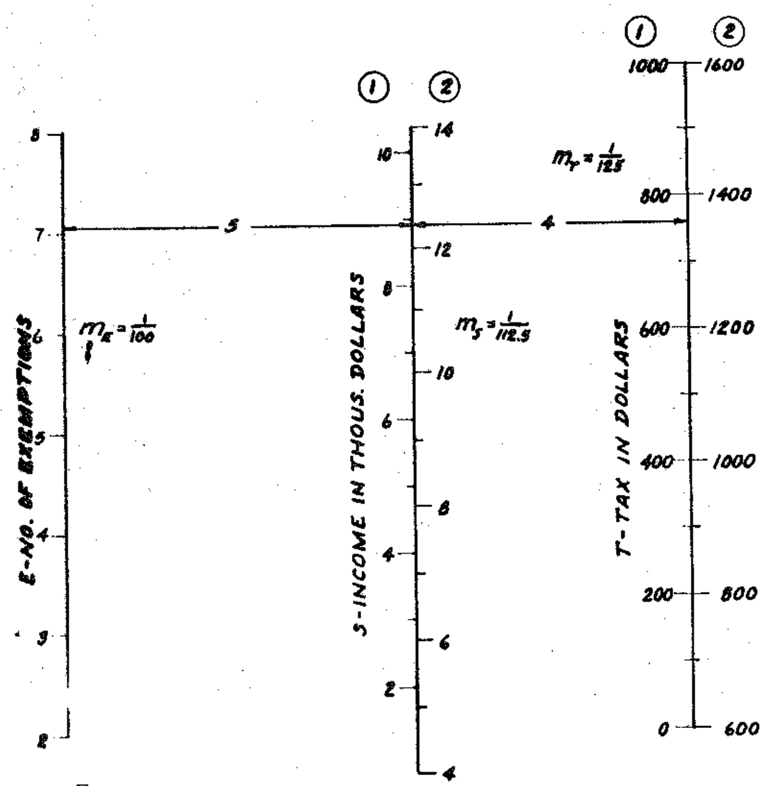
If D and H both range from 1 to 10, prepare a parallel scale nomogram for Eq. (9). The H and D scales can correspond to the C or D scale on a standard straight slide rule. The coefficient 2 on the log D term means that the functional modulus, m_D, for the diameter scale is half as much as m_H, if both are to have the same length of scale and range. The signs for the log terms of D, H, and V are all +, so that if V is made the middle scale all will increase in the same direction. The modulus, m_V, 10/3 means that the V scale is like the K scale of a standard straight slide rule. The effect of the added constant, $\log(\pi/4)$ is merely


E-NO. OF EXEMPTIONS
S-INCOME IN THOUS. DOLLARS
T-TAX IN DOLLARS
m_E = 1/100
m_S = 1/300
m_T = 1/200
5
2.5

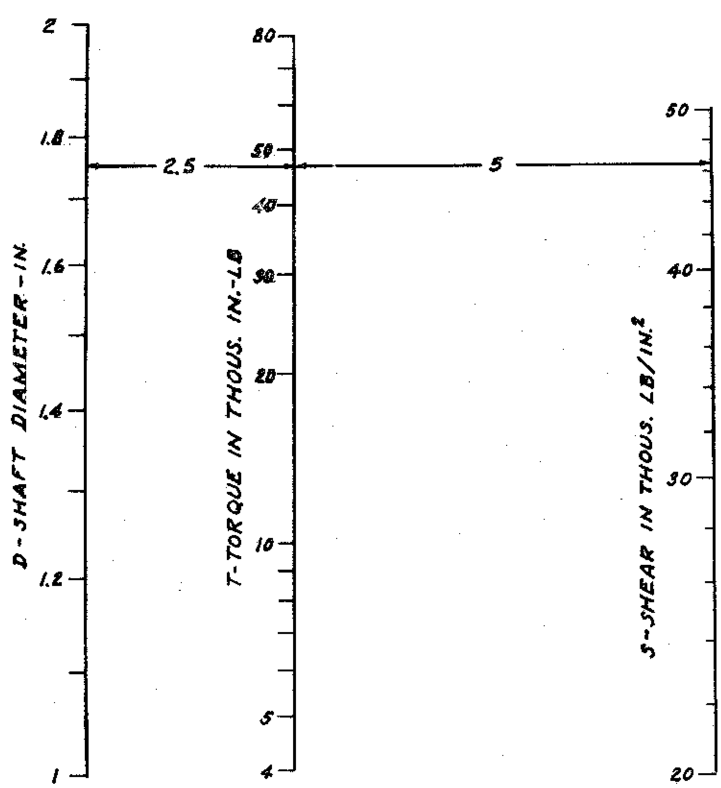
6.


D-DIAMETER IN IN.
V-VOLUME IN IN.³
H-HEIGHT IN IN.
m_D = 5
m_V = 10/3
m_H = 10
3
6
π/4

8.

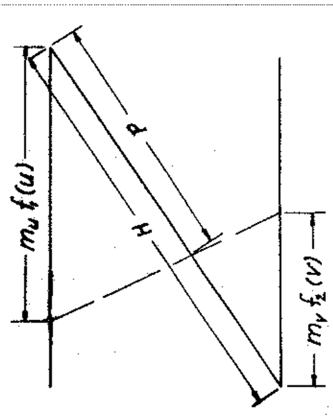

E-NO. OF EXEMPTIONS
S-INCOME IN THOUS. DOLLARS
T-TAX IN DOLLARS
m_E = 1/100
m_S = 1/112.5
m_T = 1/125
5
4
①
②

7.

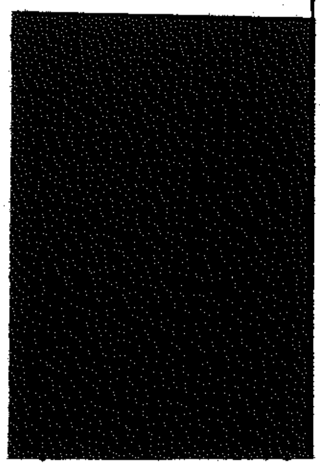

D-SHAFT DIAMETER - IN.
T-TORQUE IN THOUS. IN.-LB
S-SHEAR IN THOUS. LB/IN.²
2.5
5

9.

to shift the V-scale along its axis. The nomogram is shown in diagram form in Fig. 8.



10.



PROBLEM The equation for torsion in a shaft

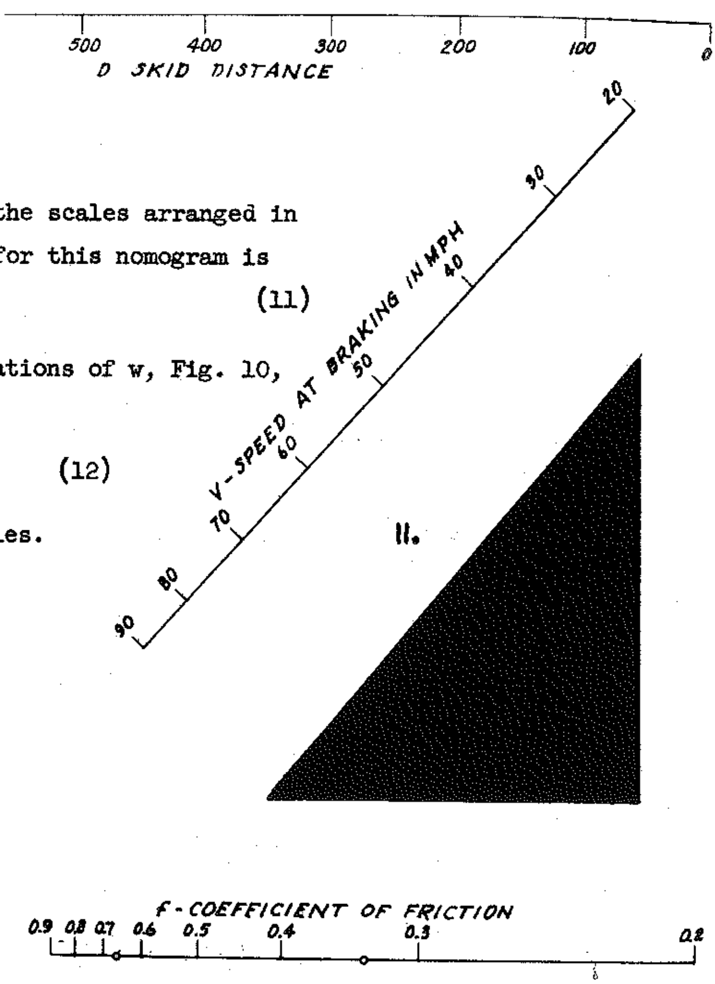
$$D = \sqrt[3]{\frac{16T}{\pi S}} \tag{10}$$

where D is diameter in inches, T is torque in in.-lb, and S is shear in lb/in.^{2}, can be put into a parallel scale nomogram. Design the chart if D ranges from 1 to 2, and S ranges from 20,000 to 50,000.

A good first step is to cube Eq. (10), take logarithms, and possibly transpose terms, making it

$$\log T = 3 \log D + \log S + \log(\pi/16)$$

A diagram of one possible design is given in Fig. 9. Constructing the D-scale is possibly laborious unless one has at hand log scales of various moduli. If m_D of 10 is selected, the D-scale is essentially like the portion from 1 to 2 on the $\sqrt[3]{\ }$ scale of some Pickett slide rules. The S-scale, for m_S of 20, is like the R-scale of a Post slide rule or the $\sqrt{\ }$ scale on some Pickett slide rules. Distances on the T-scale would be 2/3 as great as on a C-scale of one of the foregoing slide rules. Some of the value on the last scale to be prepared would need to be determined by solving an example mathematically and by laying a straight-edge across the scales.



Z- OR N-CHART

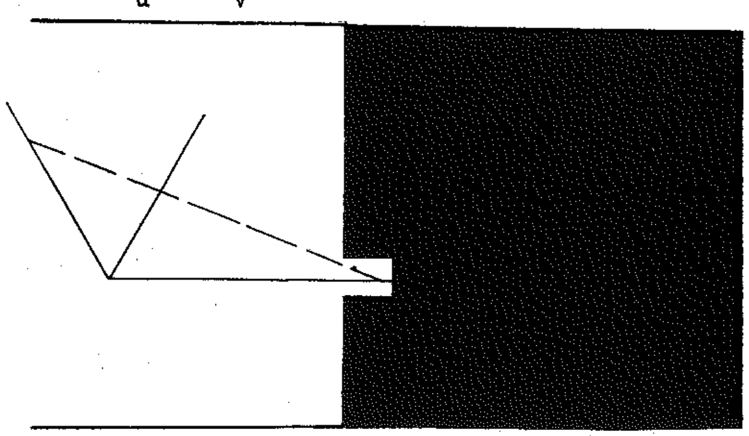
Another common form of straight scale nomogram has the scales arranged in the shape of the letters Z or N.[4] The typical equation for this nomogram is

$$f_1(u)/f_2(v) = f_3(w) \tag{11}$$

and distances along the diagonal, of length H, for graduations of w, Fig. 10, are given by

$$P = H\, f_3(w) \,/\, m_v/m_u + f_3(w) \tag{12}$$

where m_u and m_v are functional moduli of the u and v scales.



EXAMPLE Experiments in braking an automobile indicate that the length of skid marks is approximately given by

$$D = V^2/30f, \text{ or } 30D = V^2/f \qquad (13)$$

where D is skid mark length in feet; V is speed of vehicle at the time the brakes are applied, in miles per hour; f is coefficient of friction. This equation is in an appropriate form for preparing a Z-chart, with D for the diagonal scale. The terms can be rearranged in other forms, such as

$$f = V^2/30D \quad \text{or} \quad V^2 = 30D/(f)^{-1}$$

corresponding to the f-scale or the V-scale being on the diagonal. A design is carried through for the form

$$V^2 = 30D/(f)^{-1}$$

and for D from 0 to 600 ft; f from 0.2 to 0.9. If the D-scale is to be 9 in. long, then 9/(30 x 600), or 1/2000 in. is the value of m_D. If f ranges from 0.2 to 0.9, then 1/f ranges from 5 to 1.11, or a modulus, m_f, of 2 would make a scale 2(5 - 1.11), or 7.78 in. long. If the diagonal from 1/f = 0, or $f = \infty$, to D = 0 is made 15 in. long then graduation positions along the diagonal for the V-scale can be computed from

$$P = 15V^2/(2/0.0005 + V^2) \quad = 15V^2/(4000 + V^2) \qquad (14)$$

For V of 20, 30, ... 90 one may verify that the corresponding values of P are: 1.36, 2.76, 4.20, 5.78, 7.10, 8.26, 9.23, and 10.04 in. The nomogram is shown in Fig. 11.

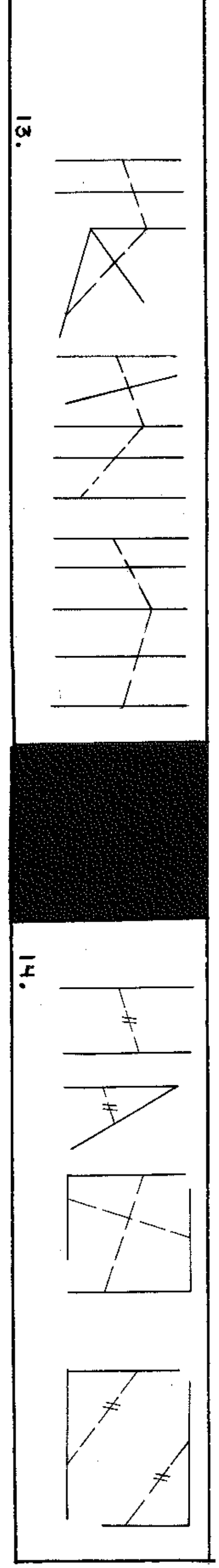
It will be observed also that if f is 0.333, then 30f = 10, or D would be equal to $V^2/10$. Thus, if a pole at f = 0.333 is used, the above V-scale graduations in steps of 10 mph can be readily located by drawing index lines from f of 0.333 to values of D of 40, 90, 160, 250, 360, 490, 640, and 810. The last two points might be located using as a pole F = 0.666, for which $D = V^2/20$, or is 320 and 405 for V of 80 and 90.

Intermediate graduations on the f-scale and on the diagonal can be located by graphical interpolation or by computation.

PROBLEM Prepare a nomogram for the same equation placing D on the diagonal scale.

A user of the chart might be advised that 0.7 is an average value of f for dry pavement, and 0.4 for wet pavement.

(appropriate values for m_v and m_f are respectively, 0.001 and 10 if the equation is written $30D = V^2/f$.)



OTHER STRAIGHT SCALE NOMOGRAMS

Another form of straight-scale nomogram for three variables is shown in diagram form in Fig. 12. No proof or example is included here.[5]

Combinations of these straight-scale forms, as indicated in Fig. 13, are useful for four variable relationships, and may be extended to five-variables and more.[6] The necessary condition which must be fulfilled is that the scale common to two elementary nomograms must have the same modulus and same direction as a part of each.

Other variations employ perpendicular index lines, or parallel index lines, as indicated in diagram form in Fig. 14.

SUMMARY

As shown, a variety of types of formulas is solvable on nomograms composed of straight scales. Many different mathematical functions can be incorporated in a graduated scale. The foregoing several examples and problems include: uniform, squared, square root, reciprocal, and logarithmic scales. These and the outline of general principles indicate the usefulness of nomograms for representing and computing with formulas which must be repeatedly solved.

Nomograms with curved scales and some other straight-scale forms not mentioned here permit even greater complexity in the formulas which can be solved.

References:

[1]See Art. 3.4 and 3.5 of Hoelscher, Arnold and Pierce, Graphic Aids In Engineering Computation, McGraw-Hill, 1952. See Chap. 2 of Levens, Nomography, 2nd Edition, John Wiley & Sons, Inc., 1959.

[2]See Art. 3.9 of Hoelscher, Arnold and Pierce, Graphic Aids in Engineering Computation, McGraw-Hill, 1952. See Chap. 3 of Levens, Nomography, 2nd Edition, John Wiley & Sons, Inc., 1959.

[3]See Art. 3.10 of Hoelscher et al. See Chap. 3 of Levens.

[4]See Art. 3.13 of Hoelscher et al. See Chap. 5 of Levens.

[5]See Art. 3.17 of Hoelscher et al. See Chap. 6 of Levens.

[6]See Arts. 3.11, 3.14, 3.15, 3.16 in Hoelscher et al. See Chaps. 7, 8, 9 in Levens.

Distinguished Service Award of the Division of Engineering Graphics to

THEODORE T. AAKHUS

DIVISION OF ENGINEERING GRAPHICS
OF THE
AMERICAN SOCIETY
FOR
ENGINEERING EDUCATION
RESOLVED:

THAT, WITH THE PRESENTATION OF THIS AWARD, THE ENGINEERING GRAPHICS DIVISION OF THE AMERICAN SOCIETY FOR ENGINEERING EDUCATION BY THIS TOKEN ACKNOWLEDGES THE MANY DISTINGUISHED SERVICES RENDERED BY

THEODORE T. AAKHUS
THROUGH THE YEARS 1933-1963

THE SOCIETY EXPRESSES ITS DEEP APPRECIATION FOR THOSE SERVICES, AND THE GREAT PERSONAL PLEASURE OF THE INDIVIDUAL MEMBERS IN HAVING HIS FRIENDSHIP.

PRESENTED THIS EIGHTEENTH DAY OF JUNE IN THE YEAR OF OUR LORD NINETEEN HUNDRED SIXTY-THREE.

Chairman of the Division — Secretary of the Division

Theodore T. Aakhus, Professor of Engineering Drawing at the University of Nebraska, is the winner of the Distinguished Service Award of 1963.

The purpose of the Distinguished Service Award is to recognize and encourage outstanding contributions to the education of young engineering students.

The recipient of the Award must have made a clearly discernible contribution to teaching in a recognized field of graphics in several of the following ways:

(A) Success as a teacher in inspiring students to high achievement
(B) Improvement in the tools of teaching
(C) Improvement in teaching through such activities as development of other teachers, testing and guidance programs
(D) Scholarly contributions to the literature and, most important,
(E) Service to the Division of Engineering Graphics of ASEE.

Professor Aakhus rates high on all these counts. He has been a member of ASEE since 1933 and has been active in the Division ever since. He has served the Division in most of its offices right through the chairmanship. Typically, Professor Aakhus held the editorship of The Journal of Engineering Drawing for six years, two elected terms, longer than anyone else in history.

During World War I Professor Aakhus served in the Navy. After he recovered his health he went to work as a lumberjack in the Minnesota woods for two years. In 1922 he left his much loved North Woods to become an engineering student at the University of Colorado. Applying his characteristic thoroughness, he was graduated near the top of his class. And in 1926 he joined the Faculty of Engineering as instructor in engineering mechanics. He is now full professor.

His industrial experience includes work in the Engineering Office of the Lincoln Telegraph and Telephone Company; in the Drafting and Design Department of the Nebraska Department of Roads, Bridge Division, Culvert Division, Right of Way Division, Highway Planning Division, and Final Estimate Division; and also in the Design and Detail of Oxygen Production Plant in cooperation with Lincoln Steel Works. He is a member of the Alpha Chapter of Sigma Tau, Engineers Club of Nebraska, Nebraska Engineering Society, and he is a Registered Professional Engineer, No. 204, State of Nebraska.

Throughout his career as a teacher Professor Aakhus has served as an influential member of the academic community on key local and national committees and has contributed to the literature of engineering graphics. But through all his service his one great concern and perhaps his greatest contribution has been his eagerness and his ability to teach and to counsel his students. His basic teaching philosophy has been to work with students individually to draw out of them their best abilities. As a result academic rank and honors rest lightly on his shoulders, for honors are constantly bestowed on him in the warmth, affection, and respect of his students. When students have been graduated and they return to the Nebraska Campus, the first man they seek out is Professor Aakhus.

He has earned many titles: lumberjack, engineer, counselor, author, editor, and teacher. The title that Professor Aakhus himself values most highly is the title of teacher.

In honoring Professor Theodore T. Aakhus with the Division's Distinguished Service Award, the Division honors itself.

Albert Jorgensen
E.M. Griswold
Irwin Wladaver, Chairman of the Committee on Special Awards

PAST WINNERS

1950	Frederic G. Higbee
1951	Frederick E. Giesecke
1952	George J. Hood
1953	Carl L. Svensen
1954	Randolph P. Hoelscher
1955	Justus Rising
1956	Ralph S. Paffenbarger
1957	Frank Heacock
1958	H. Cecil Spencer
1959	C. Elmer Rowe
1960	Clifford H. Springer
1961	William E. Street
1962	Jasper Gerardi
1963	Theodore T. Aakhus

NOMINATIONS FOR 1964

The Nominating Committee of the Division of Engineering Graphics of ASEE has selected the following slate of nominations for the offices indicated for 1964-65:

Vice Chairman
- J.S. Dobrovolny - University of Illinois
- R.O. Loving - Illinois Institute of Technology

Secretary
- Mary F. Blade - The Cooper Union
- Frank M. Hrachovsky - Illinois Institute of Technology

Director - Executive Committee (4 years, to fill the unexpired term of A. J. Philby, elected in 1963)
- R.A. Kliphardt, Northwestern University
- R.R. Worsencroft, University of Wisconsin

Director - Executive Committee (5 years)
- M.W. Almfeldt, Iowa State University
- C.C. Perryman, Texas Technological College

Division Editor (ASEE Journal)
- A.S. Palmerlee, University of Kansas
- S.M. Slaby, Princeton University

Editor of Journal of Engineering Graphics
- E.D. Black, General Motors Institite
- K.E. Botkin, Purdue University

Continued on page 11

MEMORIAL STUDENT CENTER
TEXAS A & M UNIVERSITY
COLLEGE STATION, TEXAS

THEME: Engineering Graphics--An essential discipline of the engineering profession

WEDNESDAY, JANUARY 8

Memorial Student Center
(MSC)

Leave College Station for Houston 8:00 a.m. Arrive Houston 10:30 a.m. for inspection trip of the Dome Stadium. Dome Stadium-641 ft. 10 in. dia. at top and cooled with 6,000 tons of air conditioning. Courtesy Wilson, Morris, Crane, and Anderson-Architects. Trip arranged by Professor A.P. McDonald, Rice University.

Board the "Sam Houston" 2:00 p.m. at the San Jacinto Monument for trip up the Houston Ship Channel. Limited to 100 people.

Arrive back in College Station 6:00 P.M.

REGISTRATION 4 to 8 p.m.
Serpentine Lounge

EXECUTIVE COMMITTEE DINNER
(For Executive Committee Members and Invited Guests)

6:30 p.m. Rooms 2C & 2D

7:00-10:00 SOCIAL HOUR
For all members, wives and guests. Refreshments.
Ballroom

THURSDAY, JANUARY 9

MSC
Morning

8:00-10:00 REGISTRATION
Serpentine Lounge

8:00-9:45 OPEN HOUSE

Engineering Graphics Department, Engineering Building, Room 311.
Refreshments

MSC
Assembly Room

OPENING REMARKS
W. E. Street
Texas A & M University

10:00-10:15 WELCOME ADDRESS

Dean Fred J. Benson, College of Engineering, Texas A & M University

10:15-10:45
Presiding - B.L. Wellman, Worcester Polytechnic Institute

"Some of the Engineering Problems Encountered in Creating a City for 200,000 People." Del E. Webb Corporation Representative.

10:45-11:15
"A Study of Engineering Graphics." Ernest C. Schamehorn, West Virginia Institute of Technology.

11:15-11:30
"Solution to the Duplication of the Cube." Clarence E. Hall, Engineer, Day & Zimmermannm Philadelphia, Pennsylvania.

11:45 PICTURE

Front Steps - MSC

12:15 LUNCHEON
Ballroom

Presiding - Robert H. Hammond, United States Military Academy

"Graphics as Viewed by a Consulting Engineer." Edsel J. Burkhart, Spencer J. Buchanan and Associates.

Afternoon

MSC
Assembly Room

2:00-2:20 Presiding - Hugh P. Ackert, University of Notre Dame

"Automation in Graphics". B. F. K. Mullins, Texas A & M University.

2:20-2:50 Computer Plotter Demonstration. Joe Williams and Rodney B. Murray, Kemco, Incorporated.

2:50-3:20 "Simulate to Stimulate." Robert D. LaRue, Colorado State University.

3:20-3:50 "Place of Graphics in Computers." E. H. Brock, Computation and Data Reduction Division, NASA, Houston

COMMITTEE MEETINGS

4:00-5:00 Graphics Division Committee meetings. Industrial Representatives Committee Meeting. Rooms to be announced.

ANNUAL BANQUET
MSC

6:30 Presiding - B. L. Wellman, Worcester Polytechnic Institute

"American Agriculture." Reagan Brown, Texas A & M University.

Entertainment - Singing Cadets
Director: Bob Boone.
Ballroom

FRIDAY, JANUARY 10

MSC
Morning

8:00-8:45 SOCIAL HOUR
Rooms 2C & 2D

8:45-9:30 Assembly Room

Presiding - Jerry S. Dobrovolny, University of Illinois

"Drafting in Industry"
W. R. (Dede) Matthews, Matthews & Associates - Architects & Engineers, Bryan, Texas

9:30-10:30 PANEL DISCUSSION

"Graphics' Needs of Industry."
Assembly Room

Presiding - Ken E. Botkin, Purdue University

Moderator - K. E. Botkin, Purdue University

Panelist

B. J. Whitworth, Hughes Tool Co., Houston, Texas

B. J. Armstrong, Ling-Temco-Vaught, Inc., Dallas, Texas

10:30-11:50
AIRBRUSH METHODS & DEMONSTRATIONS

Assembly Room

L.G. Whitfield, Engineer's Artist, Houston.

Eugene R. Tanner, Jr., Technical Illustrator, Houston.

Frank Nagle, Industrial Designer and Illustrator, Houston.

12:00-1:00 DUTCH LUNCHEON
MSC

Presiding - B. L. Wellman, Worcester Polytechnic Institute

Cafeteria and Dining Room

1:00-4:00
TOURS FOR INTERESTED PARTIES

LADIES PROGRAM TO BE ANNOUNCED

Dear Editor Blade:

I have read with increasing interest the articles in "The Journal" concerning the emphasis of creativity and design in engineering graphics courses and I heartily agree with those who advocate introducing the freshmen engineering students to "open-ended" problems. A present objective of mine is to convince the members of the General Engineering Department at the University of Washington that emphasis on design and development of creative thinking should be officially incorporated into our curriculum. I would appreciate any comments, suggestions, references, etc., from you concerning graphics curriculums which do emphasize design. Thank you.

Sincerely,
WILLIAM S. CHALK
Assistant Professor
Department of General Engineering
Univ. of Washington

Dear Mary:

I expect you have survived the Philadelphia meeting and are about ready to start the fall semester with schoolwork.

I am wondering if you saw the report as published in the Technical Survey World Report for June 29, 1963, Volume 19, No. 26, page 453. The statement to which I refer is as follows, "Do you know the Meissner Engineers, Inc. went bankrupt trying to computerize production of engineering drawings and the firm was sold at auction evoking a bid of only $26,000?"

Perhaps the technical devices for making orthographic drawings are not yet sufficiently perfected to guarantee success. Therefore, perhaps we will still have an opportunity to offer instruction in engineering graphics for several years to come.

I thought you might like to know the above information.

Sincerely yours,
Ralph T. Northrup
Head of the Department
of Engineering graphics

A Note on DG-4D

To the Editor of the JOURNAL:

Descriptive geometry of four dimensions, DG-4D, must be a fascinating subject. Theoretically, it doesn't exist; Father Monge defined descriptive geometry as a method of representing three-dimensional objects by pairs of two-dimensional graphic objects. This is what it comes down to. But in the May issue you ask for recommendations about possible publication of a paper entitled, "Descriptive Geometry of Four Dimensions," by Ernesto S. Lindgren.

You say that Professors Adams and Slaby both favor publication of Lindgren's paper. Presumably they both understand what Lindgren has to say or at least a substantial part of it. I haven't seen Lindgren's "DG-4D;" even so, I hope you find a way to publish it, serialized if necessary, precisely because I don't understand what DG-4D can possibly mean.

On the other hand analytic geometry deals readily with three-dimensional space; I can see and find my way reasonably well through x-, y-, and z-coordinates. With some additional agony I can accept an extension into four-dimensional space provided I don't have to try to represent it by means of two-dimensional objects in the erudite but also recondite manner of Professor Arvesen of Norway. I can even accept the x-, y-, z-, u-,..., n- coordinates of Professor Steve Coon's extension of analytic geometry into space of n-dimensions; whether I do or do not understand it is irrelevant, except to my psychiatrist.

I'm strictly a two-dimensional man. I can take two-dimensional objects and add them up to a three-dimensional object. I can not take three two-dimensional objects and add them up to a four-dimensional object. For me therefore, there is no DG-4D. By definition descriptive geometry is for the three-dimensional birds. Four-dimensional descriptive geometry is for the other birds.

Cordially
Irwin Wladaver
Associate Professor of
Engineering Graphics
NYU, School of Engineering and Science

A Note on Educational Experimentation

To the Editor of the JOURNAL:

Professor Maurice E. Hamilton made certain unwarranted statements in his article, "A New Approach to Teaching Graphics," in the May, 1963, JOURNAL. It is clear to me that Professor Hamilton had decided in advance what conclusions ought to emerge from his study. Now there's nothing wrong with such a beginning: in fact, if he had not had strong convictions about the probable outcome there would have been no incentive to attempt an experiment. But his assertion that certain conclusions could actually be drawn from a situation which "statistical methods...found to have been chance" makes me doubt the seriousness and credibility of his procedures. I realize that subsequently he adopted a different test and presumably a different set of criteria. But what I don't understand is why he didn't junk all the results of his first effort and why he didn't resist the temptation to draw and state conclusions for which he offered no evidence.

For example: in the middle of page 38 I read, "A frequency polygon showed that the experimental group had improved 75% over the control group; but when statistical methods were used to find if this had any significance, it was found to have been chance." To this I say that if statistical analysis indicated chance, the "improvement" claim should be entirely suppressed. There isn't the slightest reason to make a public statement about an experiment unsupported by acceptable evidence.

Another example: On the same page the last full paragraph reads, "So the results of that semester's work had to be thrown out, but valuable information was gathered from it. It was found that lecture time could be cut in half and that linework improvement was better than under the previous system of starting with graphical construction. It was also found, but could not be proved statistically, that the visualization was greatly improved and that less time could be used for isometrics, missing line, and missing view problems."

Now I ask you: if the "work had to be thrown out," what valuable information could be gathered from it, except perhaps the certainty that the procedures followed were invalid? Surely there is no justification for such unsupportable assertions. And I ask further: "If valuable information was gathered from it," why throw it out? Why not demonstrate in what way the information was valuable?

In that same paragraph Professor Hamilton claims that lecture time could be cut in half and that linework improvement was better than under the previous system of starting with graphical construction. He didn't present a shred of evidence. And he goes on to say that he also found, <u>but could not prove statistically</u>, that the visualization was greatly improved. This is a highly desirable goal to which we're all striving. Doesn't he have any support of any kind for such an important claim?

Cutting lecture time in half is easy: Just quit early. I'm sure my students would be delighted if I lectured only half the usual time. They might even be better off; surely they'd be happier. Does that mean that I would have done a better teaching job? Could be! But I'd want some proof before making a bold assertion. Intuition and hunches are all very well and when we have nothing else to depend on we have to use them. But let's not hide behind them when we have available experimental procedures that rely on statistical procedures.

Experimentation is easy to criticize, and especially educational experimentation. Pertinent elements are difficult to identify and the relationships often obscure; Proper tests are almost impossible to devise and harder yet to validate. Sometimes the best we can do is to use our judgment, hunches, intuition. But if we accept the premise that our results are going to be made to depend on statistical analysis, we have no right to use other criteria when statistical analysis fails to support the conclusions we had hoped to establish.

Professor Hamilton should be complimented for his willingness to challenge long established classroom procedures by comparing them with what he considered new or different. The fact that his first results did not satisfy him is all to his credit, for he revised everything he could in a second attempt to prove his case with more suitable data. And so while I find fault with the first half of his article, I praise him for his effort in the second half to come to grips with the tremendously important problem of visualization of three dimensions from two dimensional data, in an acceptable statistical way. I may have serious reservations about the validity of the test he finally used, that is, whether it really measures the kind of visualization he's talking about. But on this score I have no right to complain until I can devise a better test.

There is one more point I cannot pass over without comment. Professor Hamilton titles his article, "A New Approach to Teaching Graphics." By "new" he means one that would be different from the one being used at most institutions." And by this he means having his students do picture drawing at the very start of the course rather than start with linework and graphical constructions, and so on--the kind of stuff we did twenty years ago and, admittedly, some of us are still doing. But how many of us?

I assert that Professor Hamilton's approach is not new. I can't prove this assertion, but just examine the problem books that have been published during the past five or ten years. Nearly all of them emphasize pictorial drawing at the very beginning.

Does this mean that current practice, whatever it may be, makes an experiment unnecessary? On the contrary, it makes it essential, I think, to try to find out whether we're on the right track. I'm tired of following the self-appointed style setters. I'm willing to follow Dior and Schiapparelli to see what the trends are. But then I should want to get a little closer to the individual problem for a first hand investigation.

Yours truly,
Irwin Wladaver

DESCRIPTIVE GEOMETRY IN EUROPE

Dear Mary:

So far, I have visited nine engineering schools and eleven industrial firms in France, Germany, Italy and Switzerland, and one firm in Belgium. Yet to be visited are schools and firms in Denmark, the Netherlands and Italy. By the time we leave England on June 7 I hope to have a pretty good picture of engineering graphics education in West Europe, and also how engineering drawing is practiced and used in industry.

In two countries, Germany and Italy, engineering students get at least a full year of engineering drawing and some students get more than this. In Germany all students get at least a semester of instruction in descriptive geometry and many get two semesters. In Italy, at the University of Naples, one year of "geometry" including elements of descriptive geometry is mandatory. However, at the Polytecnico at Milan, descriptive geometry as such has been dropped, although certain aspects are taught in the first year of engineering drawing (taught by professors of architecture). These observations are based on visits to the University of Naples, Polytechnico; Milan, Techische Hochschule at Aachen, and an engineering school at Duisburg.

In France (one school at Poitiers and two in Paris) no courses in engineering drawing or descriptive geometry are taught. One school gives an entrance exam in drawing and descriptive geometry, however. French students entering such schools have had one more year of high school than ours and most of them have had some industrial experience. Therefore one might say that these schools, with very small enrollments, start at the sophomore level.

There are engineering schools of different levels in Switzerland (as well as in Germany). At the lower-level school drawing and descriptive geometry are taught in small amounts. At the higher-level school, students are "expected" to know engineering drawing through dimensioning, but not tolerancing.

All this will be explained at greater length in a report which I will write this summer and which should be printed next winter. I hope to send at least one copy of this report to each school of engineering in the United States. I hope, also, to include in the report, prints of various drawings which I have been collecting from such famous companies as FIAT, Brown-Boverie and DeMag, and from some lesser-knowns. The computer has not occupied such a prominent part in industry or education in Europe, yet. But this will probably change within the next few years as Europe begins to feel the competition getting keener, and as European manufacturers become more active. IBM is the leader at the moment

Cordially
Charles Baer

PROGRESS OF NATIONAL GRAPHICS STUDY

The national study of engineering graphics content conducted by Ernest C. Schamehorn, Associate Professor of Engineering at West Virginia Institute of Technology, has been completed and is entering a report-writing phase. The last questionnaire returns were received in May, 1963. Four hundred and eighty-four usable questionnaires were obtained from a total of 585 engineering educators and practicing engineers who were mailed questionnaires, for a return of 82.7%. Two hundred and fifty of 292 engineering educators replied for an 85.6% return, while 234 of 293 practicing engineers completed their forms for a percentage of 79.9%. Percentage returns by the various participating groups are as follows:

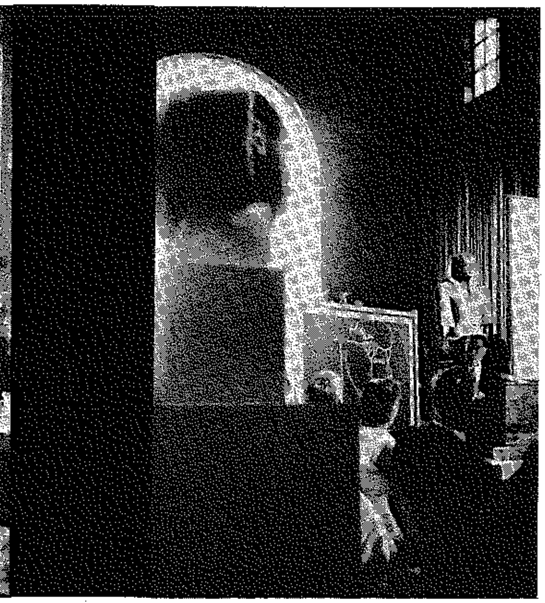
Engineering Educators	
Engineering Graphics	94.0%
Mechanical Engineering	90.2%
Electrical Engineering	88.9%
Civil Engineering	76.8%
Chemical Engineering	75.9%

Practicing Engineers	
Architectural & Structural	83.3%
Manufacturing & Production	79.7%
Operations & Maintenance	79.0%
Research & Development	78.2%

The data for each of these groups and certain combinations of the groups have been tabulated, analyzed, and interpreted, in terms of the degree of emphasis and the time required for the basic presentation of the topics listed on the questionnaires. Papers will be written in the next few months for presentation at the Mid-Winter and June meetings of the Graphics Division. Each paper will deal with different portions of the study.

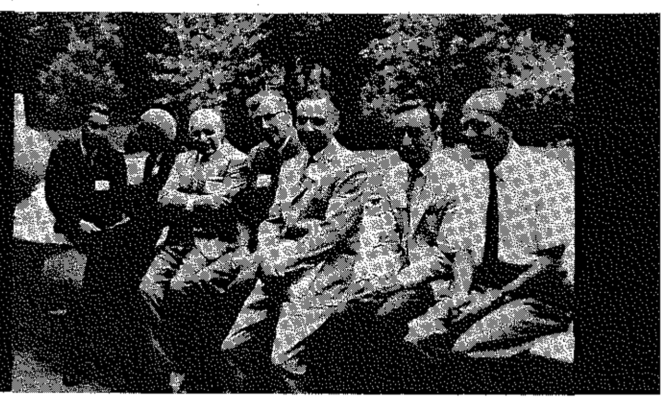
HIGHLIGHTS OF THE 1963 ANNUAL MEETING OF THE AMERICAN SOCIETY FOR ENGINEERING EDUCATION AT THE UNIVERSITY OF PENNSYLVANIA.

1964 Texas Meeting described by Bill Street.



Jim Blackman reports on Egyptian Engineering Schools in the University of Pa. Egyptian Museum.

Distinguished Award Winner of the Graphics Division - Ted Aakus, of The University of Nebraska.

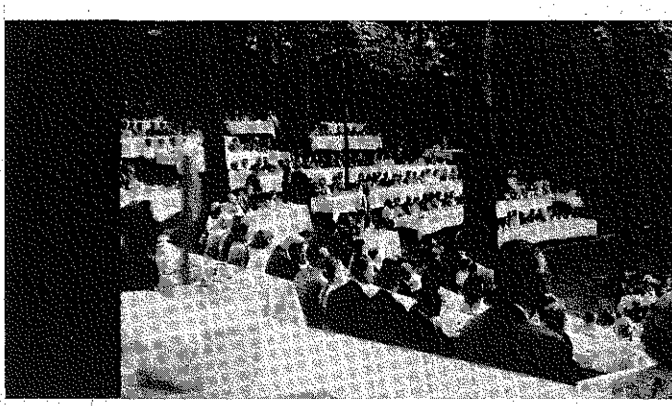


CONVERSATION LINEUP - L. to R. Blackman, Wladaver, McDonald, Buck, ?, Coons, and Borecky.

Presiding President Mat McNeary of University of Maine.

Corridor talk by Black, Mcdonald, Slaby and Reinhard.

First Descriptive Geometry Award winner Pat Borecky of University of Toronto, and Committee Chairman, Ivan Hill, Univ. of Illinois.



Pennsylvania Dutch Dinner at Swarthmore College.

Graphics Study Director Paul Reinhard.

THE ENGINEERING FUNDAMENTALS COURSE at the UNITED STATES MILITARY ACADEMY

by
Lt. Col. Robert H. Hammond, Associate Professor

The plebe (freshman) first course in engineering at the United States Military Academy is a departure from the normal course in Engineering Graphics. The U. S. M. A. course is entitled Engineering Fundamentals and consists of instruction in measurements, computers, and graphics. It spans two semesters and has a total of 90 two-hour lessons. A typical lesson consists of a lecture-conference period followed by a practice work session (laboratory). While there is no assigned homework, many cadets do outside work because of interest in the material or because they find additional study necessary to maintain proficiency. Before discussing the subject matter, certain organizational details unique to the local situation should be discussed.

ORGANIZATION

The approximately 2500 cadets who make up the United States Corps of Cadets are organized into a Brigade of two regiments. Each regiment is further divided into 12 lettered companies of approximately 104 cadets each. About 35 cadets of each company are 4th Classmen (freshmen, or "plebes" as they are called at the U. S. M. A.). The remainder are upper-classmen.

All cadets take the Engineering Fundamentals course during their plebe year, attending by "half regiment" on alternate days. The approximately 210 4th Class cadets from the first six companies of the first regiment attend during the period 0950 - 1150; those from the remaining six companies of the first regiment attend during the period 0745 - 0945. The same schedule is repeated the following day for the second regiment.

For instructional purposes, each half regiment (or group of 210 cadets) is broken down into 14 academic sections of 15 cadets per section. These sections are formed according to cadet ability in the subject matter, as indicated by the numerical grade average. The first cadet in the first section has the highest average in that "half regiment" while the last cadet in the 14th section has the lowest average. Tests are given frequently and section assignments are changed every four to six weeks so as to reflect the current grades. This frequent re-sectioning has the decided advantage that each instructor knows the level of instruction that he must present to his section. The first section instructor spends only a minimum amount of time on the basic work of the day's lesson, and devotes the remaining time to advanced work in the same area. On the other hand, the instructor who has the last section emphasizes and repeats the basic principles of the lesson and omits most advanced work. One last item of interest; any cadet who has not completely understood the day's lesson, who feels the need of review, or who is deficient (failing) may request extra instruction. This is given daily by appointment during the cadet's free time and lasts for one hour. Extra Instruction is conducted by all instructors in turn.

COURSE OF INSTRUCTION

The measurements portion of the course, as shown in the Outline of Instruction, consists of 28 lessons (31% of the total). The instruction covers linear and angular measurements, verniers, theory of errors, adjustment of errors, the meaning of significant figures, and the difference between precision and accuracy. This instruction is offered to provide a background knowledge to the cadet for future courses at the U. S. M. A. involving measurements or statistical data. Surveying is used as a vehicle for this instruction because a basic understanding of surveying facilitates the understanding of maps, which is essential for an officer in the armed forces. In fact, the last work unit of this portion calls for the preparation of a map from given survey data.

The computer portion of the course consists of 5 lessons (6%). The cadets are first introduced to the general types of computers and the types of problems for which computer programming is economical. Following this they are taught how to program problems using the West Point Basic Programming System. This is a simplified form of machine language used in conjunction with a SADSAC (Simplified Academic Design Single Address Computer) which is simulated on a GE-225 computer. During this sequence of instruction, 10 problems are assigned, including multiple loop techniques, of which the last few are run on the computer. It should be noted here that these 5 lessons do not constitute the cadet's entire exposure to the computer. Immediately following this instruction, the Department of Mathematics starts requiring certain problems in numerical analysis to be solved using the computer. Other departments, in turn, do likewise. In subsequent semesters, the Computer Center offers cadets a voluntary additional program of qualification training, and the Departments of Mathematics and Electricity offer elective courses in programming and in computer theory. The result is that cadets use the computer during each of their four years at the U. S. M. A.

As shown in the Outline of Instruction, the computer instruction is introduced during the measurements portion of the course. This is done for two reasons: 1) During the subsequent instruction, the cadets can be asked to program traverse adjustments, coordinate transformations, etc. for computer solution, and 2) In coordinating the Engineering Fundamentals courses and the Mathematics courses, this proved to be the best time to present the material.

The graphics portion of the course contains 57 lessons (63%). The first unit of this portion, Modern Graphical Techniques, which covers use of drawing instruments and geometric constructions, is given during the measurements portion (see Outline of Instruction) in order to prepare the cadets for the task of drafting a map. The remainder of the graphics portion actually consists of four different courses. The Standard and Accelerated courses follow the same outline; however, the Accelerated course, given to the upper (highest in academic order of merit) sections, covers the standard material in less than the assigned number of lessons and uses the time so gained to explore more advanced topics.

Starting simultaneously with the Standard and Accelerated Graphics courses is the Advanced course. This course is limited to those cadets who have successfully completed work in Engineering Drawing, Engineering Graphics, and Descriptive Geometry at a college or technical school. (Each year from 80 to 100 such individuals enter the U. S. M. A.) These cadets take a short, but very intense, review followed by a comprehensive examination. Those who pass this examination continue with the Advanced course; while the balance rejoin the Standard course. (Each year from 60 to 70 cadets are admitted to the Advanced course.) Those who continue, study some advanced descriptive geometry and then spend the remainder of the time on graphic solutions (see outline).

The Augmented course, as shown, splits off from the Regular course. Here, the upper half (approximately) of the class in academic order of merit is excused from the Written General Review (final examination) and the Course Review. The time so gained is used for the introduction of graphical calculus.

SPECIAL TOPICS

The topics listed in the Outline of Instruction are fairly standard with the exception of Orthographic Projection, Basic Mechanical Elements, Graphic Aids, and Application Problems. These are described below.

The work on Orthographic Projection differs from the standard presentation only in that dimensioning, sectioning, and preferred projections are taught concurrently with the introduction of orthographic projection.

The unit of instruction entitled Basic Mechanical Elements was designed to familiarize the cadets with the basic mechanical elements, their appearance, function and graphical representation. Such a unit has been found to be essential since at the U. S. M. A., as in most other schools, freshmen arrive who do not know the meaning of such mechanical terms as shoulder, chamfer, or sleeve, and do not understand the function of mechanical devices such as screw threads, gears, cams, etc. Also included in this unit is the instruction covering working sketches and drawings.

The work on Graphic Aids is a variation of the old standby, graphs and diagrams. However, here the emphasis is on the use of graphs and diagrams to present information in military training and in briefings. All officers of the armed forces, in common with most engineers and other professional men, will frequently be presenting information and data to others, or will be the recipients of information. This unit of instruction teaches cadets how to present information accurately, clearly, and simply, yet with dramatic impact. An interesting feature of this unit is a discussion-demonstration designed to alert the cadets to the fact that statistical information can be selectively presented so as to create a misleading impression. This is presented so that these potential officers will not be prone to be lead astray if data is presented in this manner in the future.

In all units of instruction of the graphics courses, problems are designed to apply the principles taught to practical situations and problems. However, the unit called "Application Problems," which is presented to the Advanced course, deserves special mention. The situations used are quite complex and require the use of most of the information covered in the preceding units of work. As an example: the cadets are given a curve of surface area versus surface elevation for a reservoir and typical stream and flood flow curves for the associated drainage area. They are told the surface elevation of the water at the start of the problem, the data for the flow over the weir, and the restrictions on the down-stream flow. The cadets are then informed that a certain type flood is due to arrive at a given time. The cadets must determine: 1. Whether the reservoir can hold all the flood water, considering the limitations on the down-stream flow, 2. The required release rate if lowering of the water level is required, and 3. The time at which the down-stream flow will exceed the limitation, if the water level is not lowered. All problems in this unit are of the type which present the cadet an unfamiliar situation that he must analyze, recognize, and break into components that can be solved by familiar graphical techniques.

This then, in brief, is the course in Engineering Fundamentals at the U. S. M. A. The overall philosophy is to present material that will be interesting and challenging to all levels of cadet aptitudes and abilities, and at the same time present the engineering fundamentals prerequisite to subsequent studies at the U. S. M. A., graduate study, and careers as officers of the Armed Forces. This is accomplished by offering different level courses and by frequent resectioning to keep each cadet in company with his intellectual peers. Such a system requires the use of data processing equipment; however, since most schools now have computer centers, the administrative burden is not unrealistic.

OUTLINE OF INSTRUCTION

SUBJECT	ATTENDANCES (LESSONS) Standard & Accelerated	Augmented	Advanced
	(Approx. 800 cadets)		
Introduction to Maps	6		
Basic Methods of Earth Meas.	12		
Introduction to Computers	5		
Application of Principles of Earth Measurements	5		
Modern Graphical Techniques	4		
Topographic Mapping (Drafting)	4		
Written General Review I	1		
		(Start Advanced Work)	
	(Approx. 720 cadets)		(80 cadets)
Validating Refresher	0		8
Pictorial Techniques	6		0
Orthographic Projection	13		0
Descriptive Geometry	12		8
Vector Geometry	5		7
Basic Mechanical Elements	6		0
		(Start Augmented Work)	
Graphic Aids (Training, Briefing)	4	3	0
Graphical Arithmetic & Algebra	0	0	4
	(360 cadets)	(360 cadets)	
Nomography	4	4	7
Empirical Equations	0	0	5
Graphical Calculus	0	4	8
Course Review	2	0	0
Application Problems	0	0	6
Written General Review II	1	0	0
	90	90	90

THE AXONOMETRIC REPRESENTATION OF N-DIMENSIONAL FIGURES

by

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(Original paper translated and prepared for publication by
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1. Let us consider the axonometric (or cylindrical) projection of a figure F_n of n dimensions in a space R_{n-1} of $(n - 1)$ dimensions. The new figure thus obtained, being F_{n-1}, can then be projected onto a space R_{n-2}. By continuing this process, the result will be a projection F_2, located on a plane.

This can be illustrated by use of the following expression:

$$\overline{P}' = \overline{P} - \frac{\overline{N}\cdot\overline{P}}{\overline{N}\cdot\overline{p}}\,\overline{p}$$

where $\overline{P}$ denotes the vector radius at the point of an R_n and $\overline{P}'$ the axonometric projection of $\overline{P}$ in the space of projection R_{n-1}. $\overline{N}$ is the normal to R_{n-1}, and we will assume that R_{n-1} passes through the origin of the coordinates of R_n. Vector $\overline{p}$ finally determines the direction of the parallel projectors.

2. We wish, in particular to develop the equations for the planar representation of the figures in an R_5. Consider first:

$$\overline{P}'_4 = \overline{P}_5 - \frac{\overline{N}_5\cdot\overline{P}_5}{\overline{N}_5\cdot\overline{p}_5}\,\overline{p}_5$$

where x_5, y_5, z_5, u_5, v_5, and a_5, b_5, c_5, d_5, e_5 would be the respective coordinates of a point of R_5 and of the vector $\overline{p}_5$. Taking the space of projection $v_5 = 0$, the coordinates of a point of the projection will be

$$x_4 = x_5 - \frac{a_5}{e_5}v_5, \quad y_4 = y_5 - \frac{b_5}{e_5}v_5,$$

$$z_4 = z_5 - \frac{c_5}{e_5}v_5, \quad u_4 = u_5 - \frac{d_5}{e_5}v_5.$$

Projecting in the three-dimensional space, $u_4 = 0$, and finally on the plane, $z_3 = 0$; we will get:

$$x_2 = x_5 - \frac{a_3}{c_3}z_5 + \frac{\begin{vmatrix} a_3 & c_3 \\ a_4 & c_4 \end{vmatrix}}{c_3 d_4}u_5 - \frac{\begin{vmatrix} a_3 & c_3 & 0 \\ a_4 & c_4 & d_4 \\ a_5 & c_5 & d_5 \end{vmatrix}}{c_3 d_4 e_5}v_5,$$

(1)

$$y_2 = y_5 - \frac{b_3}{c_3}z_5 + \frac{\begin{vmatrix} b_3 & c_3 \\ b_4 & c_4 \end{vmatrix}}{c_3 d_4}u_5 - \frac{\begin{vmatrix} b_3 & c_3 & 0 \\ b_4 & c_4 & d_4 \\ b_5 & c_5 & d_5 \end{vmatrix}}{c_3 d_4 e_5}v_5.$$

3. Numerical example: - The 5-dimensional cube has 32 apexes (corners).

1)	00000	9)	00010	17)	00001	25)	00011
2)	10000	10)	10010	18)	10001	26)	10011
3)	01000	11)	01010	19)	01001	27)	01011
4)	11000	12)	11010	20)	11001	28)	11011
5)	00100	13)	00110	21)	00101	29)	00111
6)	10100	14)	10110	22)	10101	30)	10111
7)	01100	15)	01110	23)	01101	31)	01111
8)	11100	16)	11110	24)	11101	32)	11111

and here are the 80 edges:

1-2	2-4	3-4	4-8	5-6
1-3	2-6	3-7	4-12	5-7
1-5	2-10	3-11	4-20	5-13
1-9	2-18	3-19		5-21
1-17				
6-8	7-8	8-16	9-10	10-12
6-14	7-15	8-24	9-11	10-14
6-22	7-23		9-13	10-26
			9-25	
11-12	12-16	13-14	14-16	15-16
11-15	12-28	13-15	14-30	15-31
11-27		13-29		
16-32	17-18	18-20	19-20	20-24
	17-19	18-22	19-23	20-28
	17-25	18-26	19-27	
21-22	22-24	23-24	24-32	25-26
21-23	22-30	23-31		25-27
21-29				25-29
26-28	27-28	28-32	29-30	30-32
26-30	27-31		29-31	
31-32				

By placing in particular, in (1)

$$a_3 = b_3 = 1, \quad c_3 = 2; \quad a_4 = 1, \quad b_4 = \tfrac{1}{4}, \quad d_4 = 1;$$

$$a_5 = 1, \quad b_5 = \tfrac{5}{12}, \quad c_5 = 2, \quad d_5 = 1, \quad e_5 = \tfrac{2}{3},$$

we get the representation shown in Fig. 1.

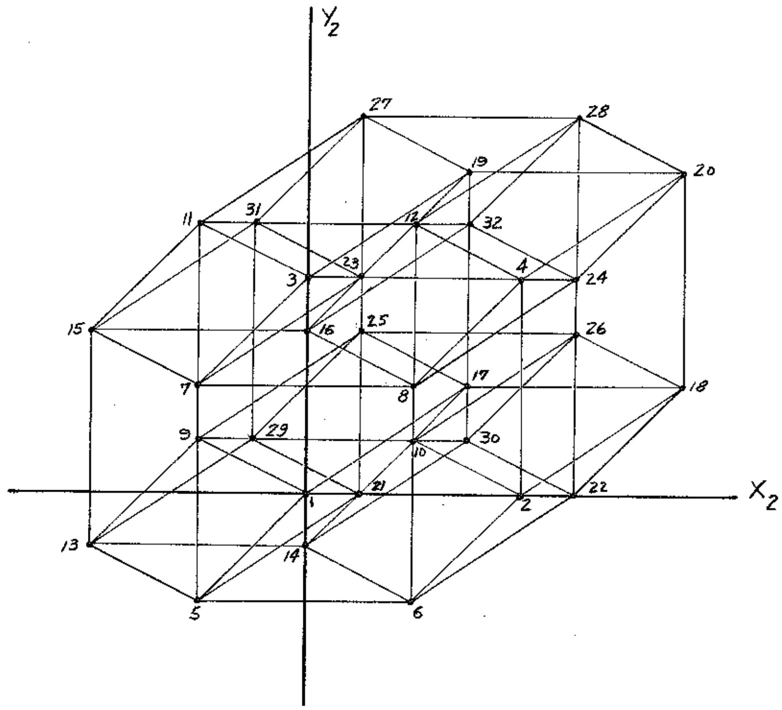


Figure 1

We see that such a projection can be obtained exactly in the case of a figure of 3 dimensions: the knowledge of the axes and the scales along these axes is enough to construct the figure in question. When large numbers of lines complicate the work and increase the possibility of making errors the analytic or symbolic manipulations would seem to be preferable.

4. Let us consider an example, where we use planes of projection instead of lines of projection.

Given in an R_4 the three 3-dimensional spaces:

$$P_i \equiv A_i x_4 + B_i y_4 + C_i z_4 + D_i u_4 + 1 = 0, \quad (i = 1,2,3,),$$

and set:

$$(2) \qquad \begin{cases} \lambda P_1 + P_2 = 0, \\ \mu P_1 + P_3 = 0, \end{cases}$$

λ and μ being two parameters. By a suitable choice of the values of these parameters, we can get the definite plane (2) to pass through a given point $P(x_4, y_4, z_4, u_4)$, and if the projecting plane is cut by a projection plane (table) as

$$z_4 = 0, \quad u_4 = 0,$$

we will obtain these expressions as the coordinates of the projection of P:

$$x_2 = -\frac{\begin{vmatrix} -1 & 1 & B_1 \\ \lambda & 1 & B_2 \\ \mu & 1 & B_3 \end{vmatrix}}{\Delta}, \quad y_2 = -\frac{\begin{vmatrix} -1 & A_1 & 1 \\ \lambda & A_2 & 1 \\ \mu & A_3 & 1 \end{vmatrix}}{\Delta},$$

the common numerator Δ being represented by

$$\Delta = \begin{vmatrix} -1 & A_1 & B_1 \\ \lambda & A_2 & B_2 \\ \mu & A_3 & B_3 \end{vmatrix}$$

Introduce here the values λ and μ taken from (2); it results that

$$\Delta = \begin{vmatrix} A_1 & B_1 & C_1 \\ A_2 & B_2 & C_2 \\ A_3 & B_3 & C_3 \end{vmatrix} z_4 + \begin{vmatrix} A_1 & B_1 & D_1 \\ A_2 & B_2 & D_2 \\ A_3 & B_3 & D_3 \end{vmatrix} u_4 + \begin{vmatrix} A_1 & B_1 & 1 \\ A_2 & B_2 & 1 \\ A_3 & B_3 & 1 \end{vmatrix}. \qquad (3)$$

Now since this is concerned with an axonometric projection, Δ must be reduced to a constant number, and we can see that this will result when at least two of the spaces $P_i = 0$ are parallel. Then if we set

$$A_3 = kA_2, \quad B_3 = kB_2, \quad C_3 = kC_2, \quad D_3 = kD_2 \ ;$$

we obtain the following for the coordinates of the projection of P:

$$\begin{cases} x_2 = x_4 + \dfrac{\begin{vmatrix} C_1 & B_1 \\ C_2 & B_2 \end{vmatrix}}{\begin{vmatrix} A_1 & B_1 \\ A_2 & B_2 \end{vmatrix}} z_4 + \dfrac{\begin{vmatrix} D_1 & B_1 \\ D_2 & B_2 \end{vmatrix}}{\begin{vmatrix} A_1 & B_1 \\ A_2 & B_2 \end{vmatrix}} u_4, \\ y_2 = y_4 + \dfrac{\begin{vmatrix} A_1 & C_1 \\ A_2 & C_2 \end{vmatrix}}{\begin{vmatrix} A_1 & B_1 \\ A_2 & B_2 \end{vmatrix}} z_4 + \dfrac{\begin{vmatrix} A_1 & D_1 \\ A_2 & D_2 \end{vmatrix}}{\begin{vmatrix} A_1 & B_1 \\ A_2 & D_2 \end{vmatrix}} u_4. \end{cases}$$

Numerical example. - In (3), set

$$A_1 = 0, \quad B_1 = 1, \quad C_1 = -1, \quad D_1 = 2;$$

$$A_2 = B_2 = 1, \quad C_2 = 2, \quad D_2 = 1.$$

With these values the projection of the 4-dimensional cube will be that shown by Fig. 2

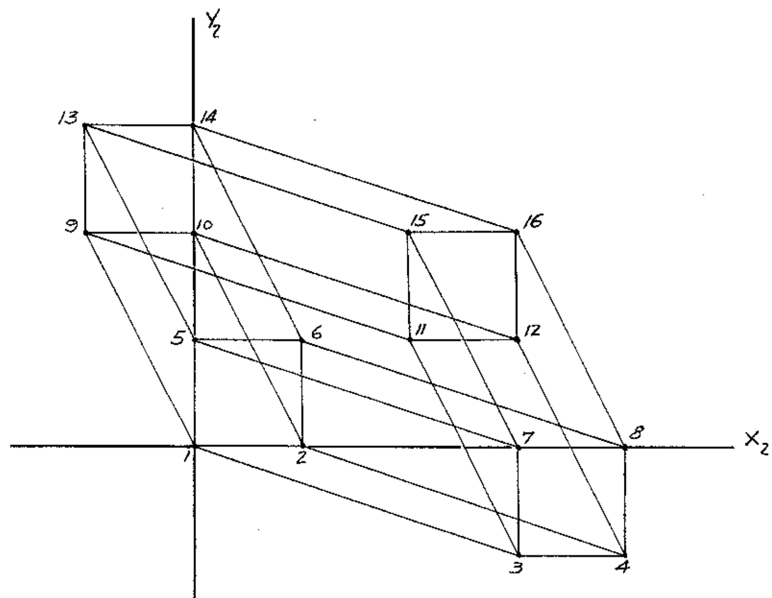


Figure 2

DESCRIPTIVE GEOMETRY OF FOUR DIMENSIONS

By C. Ernesto S. Lindgren

INTRODUCTION

The study of the high geometry has been stressed by several authors, geometricians, mathematicians, and physicists, who indicate applications in the principle of relativity, in problems of probability, and etc.

In general, the geometry applied in each case has been of a noneuclidian geometry or a synthetic study of the euclidian geometry of four dimensions.

Every geometry, euclidian or noneuclidian, can be built in several different ways, without loosing or modifying the truth of the relationships between the fundamental geometrical elements. This is possible because the geometrician has liberty in selecting a method of study.

We are taking the responsibility in developing a study of the geometry of four dimensions, using the method of the projections.

We shall describe first of all the mechanics of such an operation, using the principle of duality, which provides a very practical way for the understanding of the space of four dimensions.

THE SPACE OF FOUR DIMENSIONS

I.1. Conception by the Projective Geometry

For the geometry of three dimensions, it is postulated:

a. Two points determine a line to which they belong.
b. Three points that do not belong to the same line determine a plane.
c. One point and one line that do not belong to each other determine a plane.

Applying the principle of duality, the following is obtained, and postulated:

d. Two planes determine a line to which they belong.
e. Three planes that do not belong to the same line determine a point.
f. One plane and one line that do not belong to each other determine a point.

Other four true statements, considered as corollaries of the six postulates are:

g. If two points of a line belong to a plane, the line belongs to the plane.
h. Two lines that belong to the same point, also belong to the same plane.

Applying the principle of duality:

i. If two planes of a line belong to a point, the line belongs to the point.
j. Two lines that belong to the same plane, also belong to the same point.

The three geometrical elements, namely point, line, and plane are, as we see, related in these postulates in such a manner, that two or three of them, properly located, always determine a different one. During all this process, the geometrical element where the transformations take place, is not mentioned and there is no postulate for its determination. In other words, the space, geometrical element where these transformations are possible, is not considered in the postulates, in the assumption that, being the whole, its conception is totally understood, by postulating the relationships between its parts.

Taking the postulates a, j, d and h for a close examination, and calling the point, the space of zero dimensions, the line, the space of one dimension, the plane, the space of two dimensions, and the geometrical element where they can coexist simultaneously, the space of three dimensions, we conclude by the observations of the postulates:

1. Two spaces, under certain conditions, always determine another space with one more dimension.
   For example: two points (two spaces of zero dimension) determine a line (space of one dimension); two lines (two spaces of one dimension) that belong to the same point (condition), also belong to the same plane (space of two dimensions).
2. The reciprocal of the conclusion is also true: two spaces of same dimension, determine under certain conditions, a space with one less dimension.
   For example: two planes (two spaces of two dimensions) determine a line (space of one dimension) to which they belong; two lines (two spaces of one dimension) that belong to the same plane (condition) determine a point (space of zero dimension).
3. Only point and line are determined as the intersection of two spaces with one more dimension.
4. Only two planes are not said to determine a space with one more dimension. They are said to determine a line, space that has one less dimension.

Introducing the space of three dimensions as a new geometrical element to deal with in the postulate that says: "two planes determine a line to which they belong", and substituting plane by space and line by plane, we obtain:

"TWO SPACES (OF THREE DIMENSIONS) DETERMINE A PLANE TO WHICH THEY BELONG."

To this statement applying the principle of duality we get:
"TWO PLANES THAT BELONG TO THE SAME LINE (CONDITION) DETERMINE A SPACE (OF THREE DIMENSIONS)."

The consequences of this extension of the postulates are:

1. Existence of a space of four dimensions, for two spaces with the same number of dimensions can only coexist in a space that has one more dimension than the spaces in consideration.

2. Existence of two planes that do not belong to the same line (objective or of the infinity). There is, the intersection of two planes is a point. This condition occurs because when two spaces with the same number of dimensions do not belong to a space with one less dimension, their intersection is a space with two less dimensions.
   Example: two reverse lines (do not belong to the same point), do not intersect at all, or the "intersection" is a space with "minus one" dimension (one dimension of the line minus two).
3. Existence of spaces of three dimensions where point, line and plane are related by the same postulates and theorems established in geometry of three dimensions.
4. New postulates and theorems relating the four geometrical elements in consideration in this space of four dimensions, namely: points, lines, planes, spaces. The new relations will permit the realization of transformations that are not possible in the space of three dimensions.
   For example: the intersection of two planes can be a point, as indicated in item 2; a line simultaneously perpendicular to two planes that are not parallel; four lines perpendicular to each other and belonging to the same point; three planes perpendicular to each other and belonging to the same line; and etc.

I.2. Conception by the Analytic Geometry

In order to make observations that shall lead to the conception of a space of four dimensions, write the equations of the three geometrical elements of the space of three dimensions, using the cartesian representation:

1. Point: $ax + b = 0$;
2. Line: $ax + by + c = 0$;
3. Plane: $ax + by + cz + d = 0$.

Observations:

a. The number of variables in the equation of the geometrical element (or space) that it represents, is equal to the number of dimensions of the space, plus one.
b. The geometrical elements involved in the system of reference, and the space being represented have the same number of dimensions.
c. The number of geometrical elements in the system of reference is equal to the number of dimensions of the space being represented, plus one. This number of geometrical elements in the system is the minimum required.
d. A system of reference used for the representation of a geometrical element, is situated in a space with one more dimension than the geometrical element in question.

If we want to write the cartesian equation of a space of three dimensions we shall use the observations above and conclude:

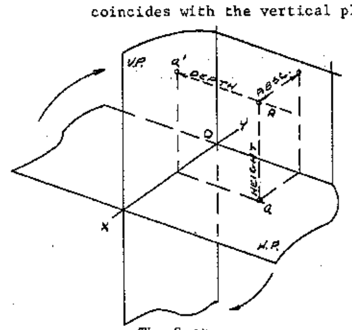
a. The equation of a space of three dimensions has four variables. It is: $ax + by + cz + dw + e = 0$.
b. The geometrical elements of the system of reference have three dimensions, there is, they are spaces of three dimensions.
c. There are four spaces of three dimensions in the system of reference.
d. The system of reference is located in a space of four dimensions.

THE SYSTEM OF REFERENCE.PROJECTION ON A SPACE

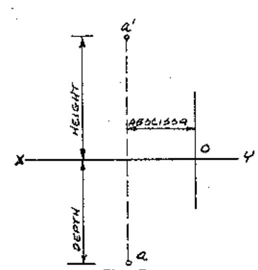
The system of reference is the same for both the analytic geometry and for the descriptive geometry.

The method of the descriptive geometry of three dimensions conceived by Gaspard Monge consists:

a. to project a point of the space on the planes of the system of reference by means of a cylindrical-orthogonal projection;
b. to rotate the horizontal plane about the ground line, until it coincides with the vertical plane.



The System of Reference



The Epure of a Point

The system of reference that we obtain with the conception of the space of four dimensions is made of four spaces of three dimensions. These spaces are perpendicular to each other.

According with the synthetic geometry of four dimensions;

Theorem: If a line is perpendicular to a space, any space which contains (belongs) the line is perpendicular to the space.

Theorem: If two spaces are perpendicular, any line in one perpendicular to their intersection is perpendicular to the other, and any line through a point of one perpendicular to the other belongs entirely to the first.

Conclusions:

1. The four spaces of the system, three by three determine four lines, perpendicular to each other and belonging to the same point;
2. The four lines, three by three, determine the four spaces perpendicular to each other;
3. The four lines two by two determine six planes, three by three belonging to the same line;
4. The line belonging to three planes is perpendicular to the fourth, and perpendicular to the space that belongs to the plane, but does not belong to the line.

In this system of reference we can omit one of the spaces, since the distance of a point to it is represented in the line intersection of the other three.

Reduced the system to three spaces, call them Σ_1, Σ_2, Σ_3. The three planes intersection of the three spaces two by two call π_1, π_2, π_3.

In order to make this notation become conservative throughout the work, establish that two planes determine the space with an index that completes the series 1, 2, 3.

Then:

planes π_1 and π_2 determine the space Σ_3 ;
planes π_1 and π_3 determine the space Σ_2 ;
planes π_2 and π_3 determine the space Σ_1 .

The intersection of the three spaces and that belongs to the three planes, call the ground line.

Basically, the projection of a point from a center C on a geometrical form F, is the intersection of the projecting line with the form F. We shall project a point of the space of four dimensions on each one of the spaces of the system of reference. In each case, the projection is the intersection of the corresponding projecting line with the space. Introducing an artifice, so that the projections will be represented in a plane, we rotate two spaces about the ground line, until they coincide with the third. We have now a situation similar to the system of reference of the descriptive geometry of three dimensions. The two projections on the rotated spaces will be situated with the projection on the fixed space, on a perpendicular to one of the planes that determine this space. These two projections are now projected on the other plane of the space. Rotating one of the planes until it coincides with the other, we obtain a plane representation of the projections of a point of the space of four dimensions. Since the operation rotation about a line does not change the distance of a point, being rotated, to the line, the distance of a point to a space, which is the distance of the projection of the point to the ground line, remains unchangeable, at the end of the process.

All the projections made are from a point of the infinity in a perpendicular direction to the space.

We say then, that the distance, in the epure, from the projection of a point to the ground line is the real distance from the point in the space of four dimensions to the space of projections.

To determine the projection of a point on a space we shall establish the conditions of belonging between point, line, plane and space. The conditions are:

a. A point belongs to a space if belongs to a line of the space;
b. A line belongs to a space if belongs to a plane of the space, or if belongs to two points of the space;
c. a plane belongs to a space if belongs to two lines of the space, or if belongs to a line and a point of the space, or if belongs to three points of the space.

Consider a space E of projection, a center C of projections, and a point A, to be projected on the space from the point C.

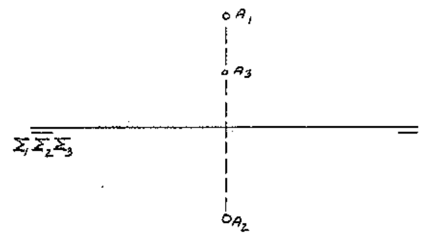
The projecting line is AC. To determine the intersection of AC with the space, which is the projection of the point, we have to determine a plane of the space, that belongs to a line which contains the projection, that we call "a". To the projecting line, which is in the space of four dimensions, belongs a infinite number of spaces. We select one of them and find the intersection with the space E. The result is a plane, that we call P. From the infinite number of planes that belong to AC, we select one, plane Q, that intersects P along a line MN. AC and MN belong to the same plane Q and are concurrent, in a point. This point also belongs to the plane P, which in turn belongs to the space E. Under these conditions, we have a point that belongs to a line of a plane in the space E: is the projection "a" of the objective point A, on the space E, from the center C. The space that belongs to the projecting line is the projecting space; the plane Q is the projecting plane.

When projecting on three spaces of the system, we can use the same projecting space to obtain the three projections of the point.

The question of considering the regions of the space of four dimensions, situated between the spaces of projection, can be considered immaterial. The method of the descriptive geometry has the objective of representing the geometrical forms in a plane form. If we have the projections of the points of the geometrical forms, this information is all that is necessary for the determination of the metrical and graphical properties.

REPRESENTATION OF THE POINT

A point is represented in epure by its three projections on the three spaces of the system.



Let us take the projections two by two and organize the following group: A_1 and A_2; A_2 and A_3; A_1 and A_3.

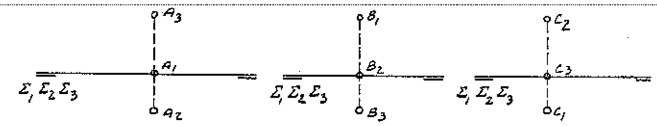
If we eliminate one of the planes that determine with another, one of the spaces of projection, the system of reference is reduced to only one space. For example, if we eliminate the plane π_1 the only remaining space is Σ_1 determined by the planes π_2 and π_3 Consequently, the system of reference is reduced to two planes of a space, there is, we operate with the descriptive geometry of three dimensions. The projections of the point are A_2 and A_3, that are found on the planes π_2 and π_3. If we eliminate π_2, the remaining space is Σ_2, determined by the planes π_1 and π_3. The projectio of point are A_1 and A_3, on the planes π_1 and π_3. If we eliminate the plane π_3, the remaining space is Σ_3, determined by the planes π_1 and π_2. The projections of the point are A_1 and A_2 on the planes π_1 and π_2.

We conclude: if we have two points determining a line, operating with two projections only, and applying one of the methods of the descriptive geometry to obtain the real length of a segment, we will obtain the real length of the projection of the segment on the space. After this is done, working with this segment and the other projection of the line, applying again the method of the descriptive geometry, we will have the real length of the segment of the space of four dimensions.

ESPECIAL POSITIONS OF THE POINT

a. Point that belongs to a space of projection.

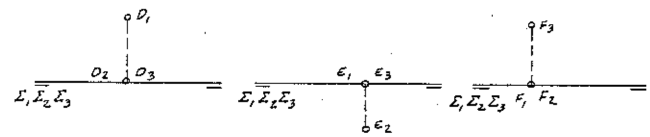
If the point belongs to a space, the distance to the space is zero. Since in the epure this distance is represented by segment limited between the projection on the space and the ground line, we conclude that this projection is on the ground line.



Point in the Space Σ_1 Point in the Space Σ_2 Point in the Space Σ_3

b. Point that belongs to one of the planes π_1, π_2 or π_3.

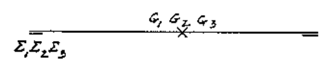
This point belongs to two spaces, for each is the intersection of two spaces of projection. Two projections of the point are on the ground line. They are the projections on the spaces that determine the plane in question.



Point of the Plane π_1 Point of the Plane π_2 Point of the Plane π_3

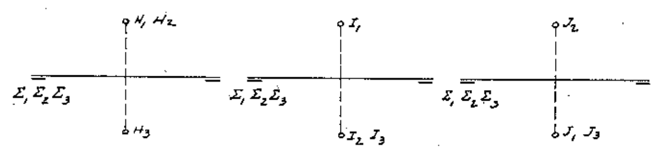
c. Point that belongs to the ground line.

This point has the three projections on the ground line, for it belongs to the three spaces.



d. Point that has two projections coinciding.

In this case the point belongs to the geometrical loci of points equidistant to two spaces of projection, which is the bisector space of the hyper-dihedral angle which cells are the two spaces of projection. The face of the hyper-dihedral angle is the intersection of the two spaces.



Point Equidistant of Σ_1 & Σ_2 Point Equidistant of Σ_2 & Σ_3 Point Equidistant of Σ_1 & Σ_3

Observation about the points H, I, and J.

In the study of the descriptive geometry of three dimensions, is demonstrated that the projections of a plane figure, the intersection of the plane with the bisector plane of the second and fourth dihedral angles (which is a line having in the epure the two projections coinciding), and the point of the infinity of the lines of recall (perpendicular to the ground line) form a system of homology, that is called an affinity because the center of homology is a point of the infinity.

In the case of the descriptive geometry of four dimensions, is possible to determine, in a general space, a line that has two projections coinciding. This line, or better say, the coinciding projections of the line, again is the axis of homology, or affinity, of the system of homology in the plane of a figure that belongs to this line. Consequently, there are three systems of homology, formed by the projections of the points, two by two as homologous points, the two coinciding projections of the line of the plane as axis of homology, and the point of the infinity of the line of recall, as the common center of homology.

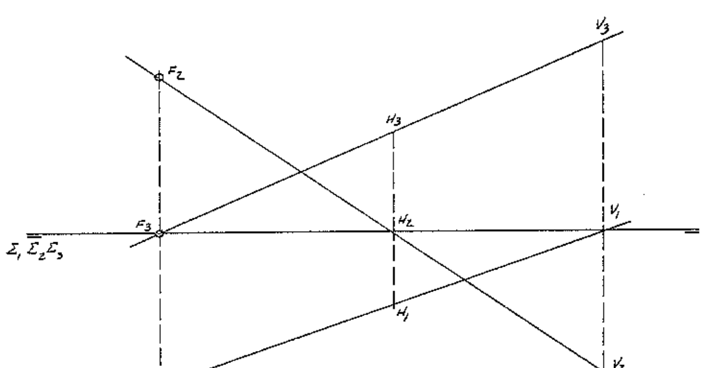
REPRESENTATION OF THE LINE

The condition of belonging between line and point, that could be demonstrated with the help of the theorems of the synthetic geometry of four dimensions is: "A point belongs to a line if the projections of the point are found on the projections of the line, with the same index number, there is, the projection of the point on the spaces Σ_1, Σ_2 and Σ_3, on the projections of the line on Σ_1, Σ_2 and Σ_3 respectively."

In a line there are points that should be determined, permitting the analysis of important facts about the position of the line in the space of four dimensions, in relation to the spaces of projection. Such points are: the intersection of the line with the spaces of projection, the intersection of the line with the bisector spaces, and the intersection of the line with the planes that determine the spaces of projection. The last point is obtained if the line satisfies certain conditions.

1. Intersection of the line with the spaces of projection.

If a point belongs to a space of projection, the distance of the point to that space is zero, and the projection is found on the ground line.



2. Intersection of the line with the planes that determine the spaces of projection.

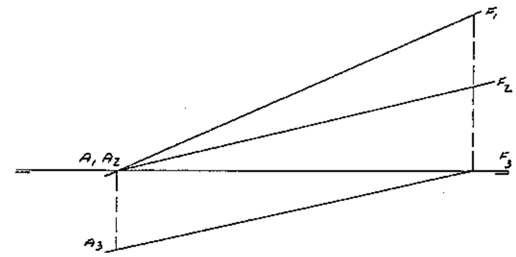
These points should satisfy two conditions:

a. Belong to the line;

b. Belong to one of the planes.

From that, conclude:

"A line intersects one of the planes π_1, π_2, or π_3 if the projections of the line on the spaces that determine the plane in consideration, are concurrent on the ground line."

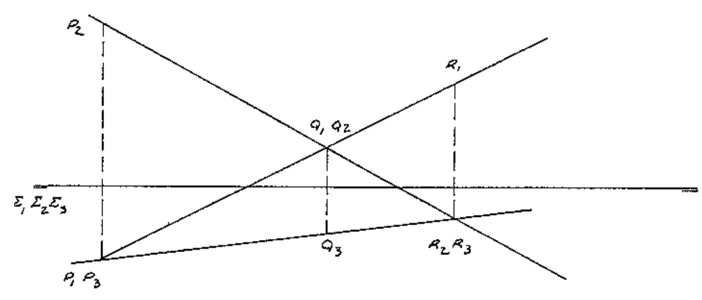


If the projection A_1 is on the ground line, the point (A) is the intersection of the line with the space Σ_1.
If A_2 is on the ground line, the point (A) is, also, the intersection of the line with the space Σ_2.
The point (A) belongs to the spaces Σ_1 and Σ_2, and belongs to the intersection of them, there is, to the plane π_3.

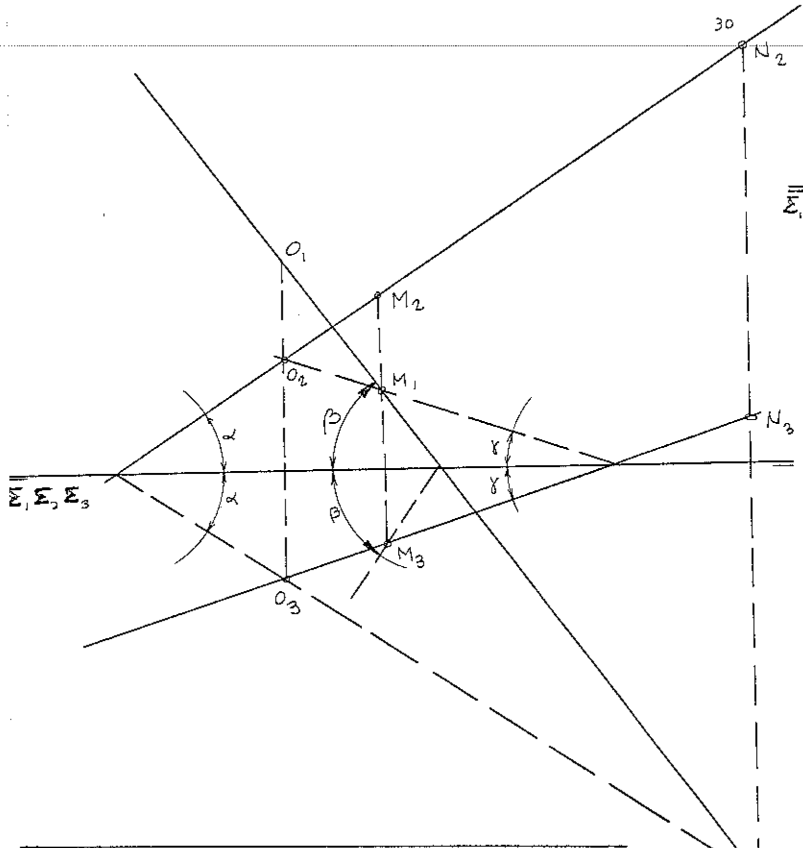
Practical way to identify which plane the line intersects: "The line intersects the plane that has the same index number of the projection of the point that is not on the ground line."

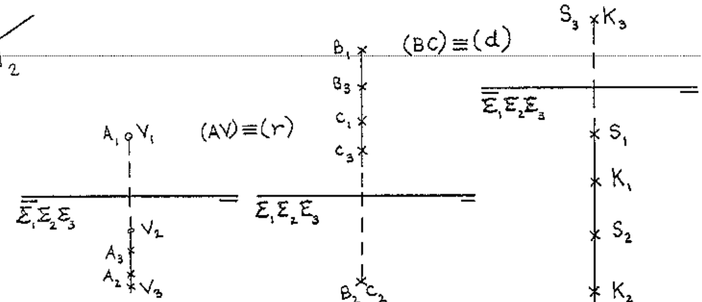
3. Points of the line that are equidistant to two spaces of projection. Intersection with a bisector space.

In the epure of a line, we observe the existence of points that have two projections coinciding. The points (P), (Q), and (R) have this particularity, and are equidistant to two spaces of projection.



In the study of the point we did not mention the points that have two projections symmetrical in relation to the ground line. If this condition exists, the point is also equidistant to two spaces of projection. In the following epure, the points (M), (N), and (O) are determined by a graphical process, so that they satisfy the condition of having two projections symmetrical in relation to the ground line.

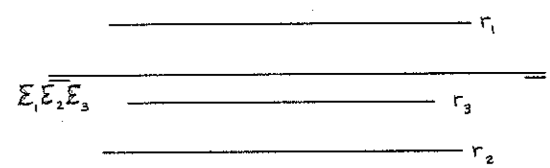




Line Perpendicular to Σ_1	Line Perpendicular to Σ_2	Line Perpendicular to Σ_3

c. LINE PARALLEL TO THE GROUND LINE.

The line is parallel to all spaces of projection. The three projections of the line are parallel to the ground line. All the intersections of the line with the spaces of projection are coinciding with the point of the infinity of the ground line, in the space of four dimensions.



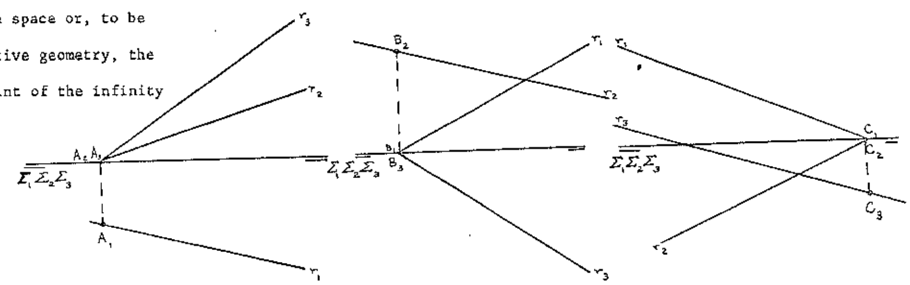
d. LINE THAT INTERCEPTS A PLANE.

The conditions for the possibility of this interception were already established.

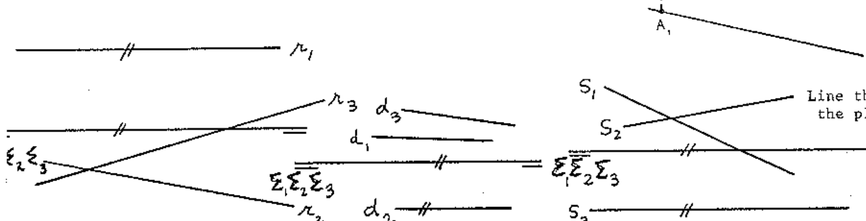
4. Especial positions of the line in relation to the spaces of projection.

a. LINE PARALLEL TO A SPACE

The projection of line on that space is parallel to the ground line, for the line does not intersect the space or, to be conservative with the definitions in the projective geometry, the intersection of the line with the space is a point of the infinity of the space of four dimensions.



Line that intercepts the plane π_1 — Line that intercepts the plane π_2 — Line that intercepts the plane π_3



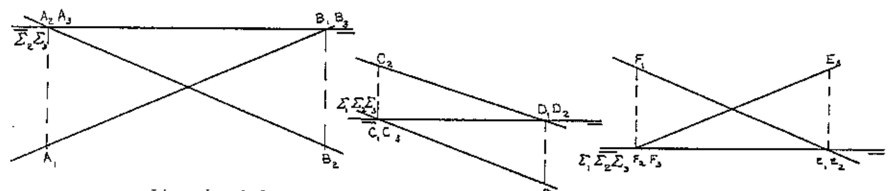
Line parallel to Σ_1 — Line parallel to Σ_2 — Line parallel to Σ_3

b. LINE PERPENDICULAR TO A SPACE

The projection of a line (r) in this space is reduced to a point, which is the geometrical loci of the projections of all the points of the line on the space. The projections of the intersection (V) between the line and the space are on the same line of recall and respectively on the projections of same index of the line. We conclude that the two other projections of the line are perpendicular to the ground line and coincide.

e. LINE THAT INTERCEPTS TWO PLANES.

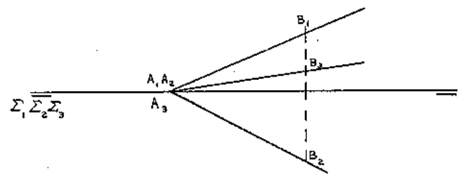
In that case the line belongs to the space determined by the two planes. The projection of the line on that space is found on the ground line.



Line that belongs to Σ_3 Line that belongs to Σ_1 Line that belongs to Σ_2

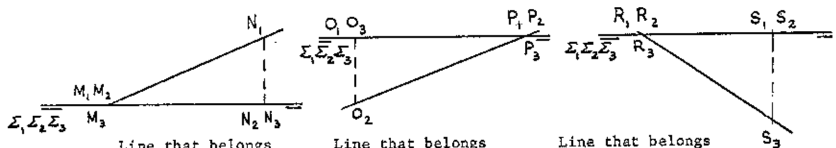
f. LINE THAT INTERCEPTS THE THREE PLANES.

The line has one point in the ground line.



g. LINE THAT BELONGS TO A PLANE.

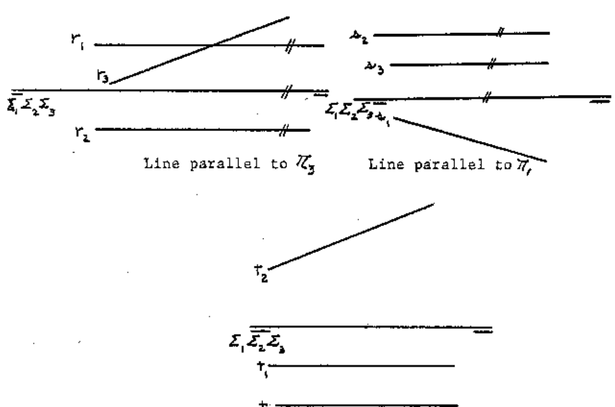
The line in that case has one point on the ground line.



Line that belongs to π_1 Line that belongs to π_2 Line that belongs to π_3

h. LINE PARALLEL TO TWO SPACES.

The projections of the line on these two spaces are parallel to the ground line.



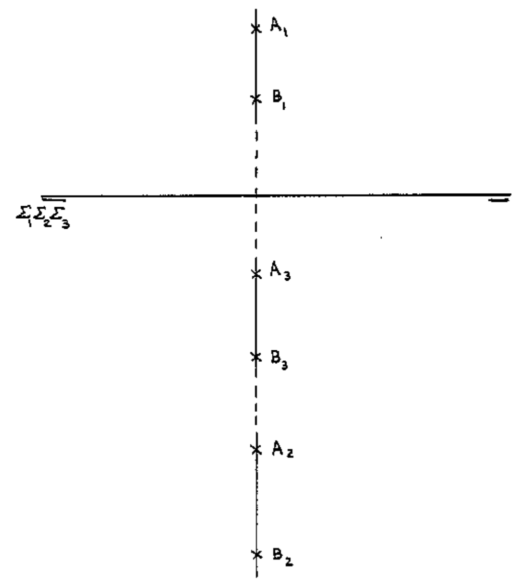
Line parallel to π_3 Line parallel to π_1

Line parallel to π_2

i. LINE PERPENDICULAR TO THE GROUND LINE

The projections of this line are perpendicular to the ground line.

The line should be characterized in the epure by the projections of two points.



REPRESENTATION OF THE SPACE

The study of the space is presented before the study of t plane, because the problems related with the last, are conditioned the establishment of the conditions of belonging. The problems of intersection between two planes, between line and plane etc. are possible in the descriptive geometry of three dimensions because th geometrical elements in question, belong to the same space. In the study of the descriptive geometry of four dimensions, the problem is possible, if the geometrical elements belong to the same space.

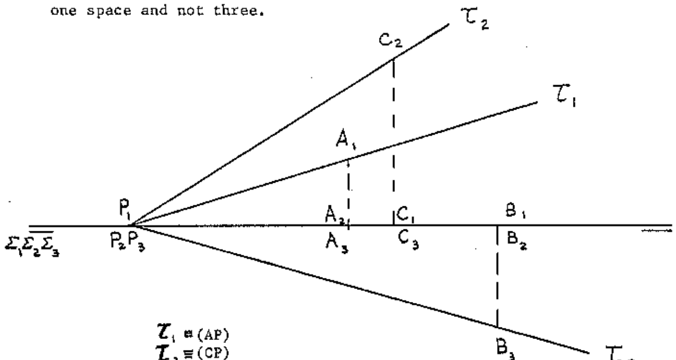
Analyzing the problems related with two spaces, plane and space, and plane and line, we conclude that they are possible, becau the geometrical elements belong to the same space of four dimensions However, the following theorem leads to the conclusion that the problems related with planes, are not always possible: "one plane has only one line belonging to a space that does not belong to the plane."

Demonstration:

The plane is determined by two lines. If each line has tw points in the space considered, they both belong to it, so does the plane that they determine. But since the theorem only establishes t the plane has only one line in the space, the second line cannot belong to the same space, for this contradicts the hypothesis of the theorem.

From this we conclude that a space $\mathcal{T}$ intercepts each plane π_1, π_2, and π_3, along one line only. These three lines are concurrent in the ground line, for being this line the intersection of π_1, π_2, and π_3, and not belonging to the space $\mathcal{T}$, has in it only one point, that we call (P). This point (P) belongs to the space $\mathcal{T}$, to the planes π_1, π_2, π_3, and to the ground line. It is the intersection of the three lines intersections of the space with the planes π_1, π_2, π_3. We call the three lines τ_1, τ_2, τ_3. Two by two they determine three planes. Each one of these planes belongs to one space of projection. We conclude that the three planes are the intersections of the space $\mathcal{T}$ with the spaces of projection Σ_1, Σ_2, and Σ_3.

Since it was postulated that two planes determine one space, we shall demonstrate that the three planes in question, represent only one space and not three.



$\tau_1 \equiv (AP)$
$\tau_2 \equiv (CP)$
$\tau_3 \equiv (BP)$
$\tau_1\tau_3 \equiv$ Plane α
$\tau_1\tau_2 \equiv$ Plane β
$\tau_2\tau_3 \equiv$ Plane γ

Assume that: $\alpha\,\beta \equiv$ Space $\mathcal{T}'$; $\alpha\,\gamma \equiv$ Space $\mathcal{T}''$; $\gamma\,\beta \equiv$ Space $\mathcal{T}'''$

α and γ belong to the line τ_3
β and γ belong to the line τ_2
α and β belong to the line τ_1

From this we conclude:

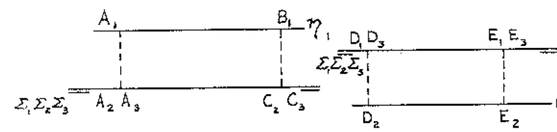
τ_1 belongs to $\mathcal{T}'$ and to $\mathcal{T}''$ because belongs to α
τ_1 belongs to $\mathcal{T}'''$ because belongs to β
τ_2 belongs to $\mathcal{T}'$ and to $\mathcal{T}'''$ because belongs to β
τ_2 belongs to $\mathcal{T}''$ because belongs to γ

The plane β belongs to $\mathcal{T}'$, to $\mathcal{T}''$, and to $\mathcal{T}'''$.
With similar considerations conclude that α and β also belong to the spaces $\mathcal{T}'$, $\mathcal{T}''$, $\mathcal{T}'''$.
Consequently, $\mathcal{T}' \equiv \mathcal{T}'' \equiv \mathcal{T}''' \equiv \mathcal{T}$. There is only one space.

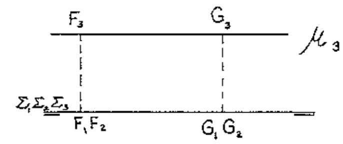
1. Especial positions of the space in relation to the spaces of projection.

   a. SPACE PARALLEL TO A SPACE OF PROJECTION.

The space is parallel to the two planes that determine the space of projection. In this case, the intersections of these planes with the space, are lines of the infinity of the space of four dimensions. The intersection of the space with the third plane, is a line parallel to the ground line.



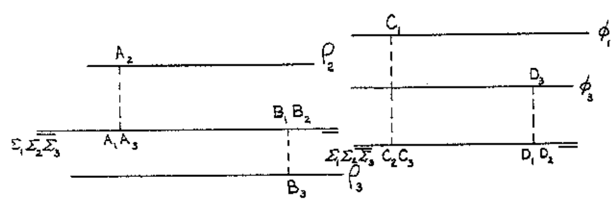
Space parallel to Σ_1 Space parallel to Σ_2



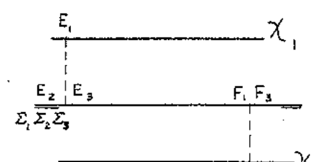
Space parallel to Σ_3

b. SPACE PARALLEL TO ONE OF THE PLANES π_1, π_2, OR π_3.

The space does not intercept the plane to which is parallel. This means that the space is also parallel to the two spaces of projection that determine the plane. The intersection with the two other planes are two lines parallel to the ground line.



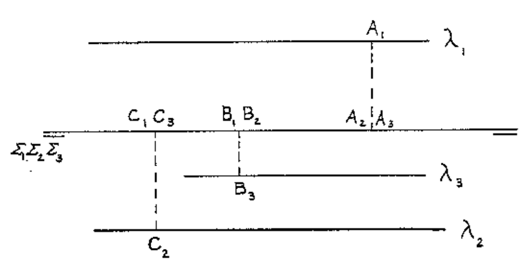
Space parallel to π_1 Space parallel to π_2



Space parallel to π_3

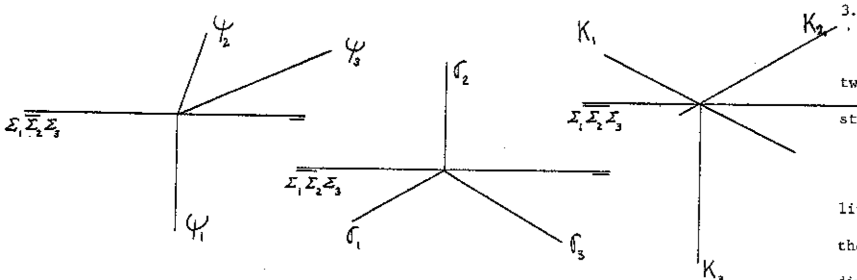
c. SPACE PARALLEL TO THE GROUND LINE.

The intersections of the space with the spaces of projection are three planes parallel to the ground line. The intersections with the planes π_1, π_2, and π_3 are three lines, also parallel to the ground line.



d. SPACE PERPENDICULAR TO A SPACE OF PROJECTION.

The two planes that determine the space of projection in question, intercept the space along lines that belong to the same point on the ground line. The third plane, being perpendicular to the other two, is also perpendicular to the space of projection that they determine. However, this plane is not parallel to the space in study and determines on it a line, that is perpendicular to the space of projection. Such a line is perpendicular to the ground line.

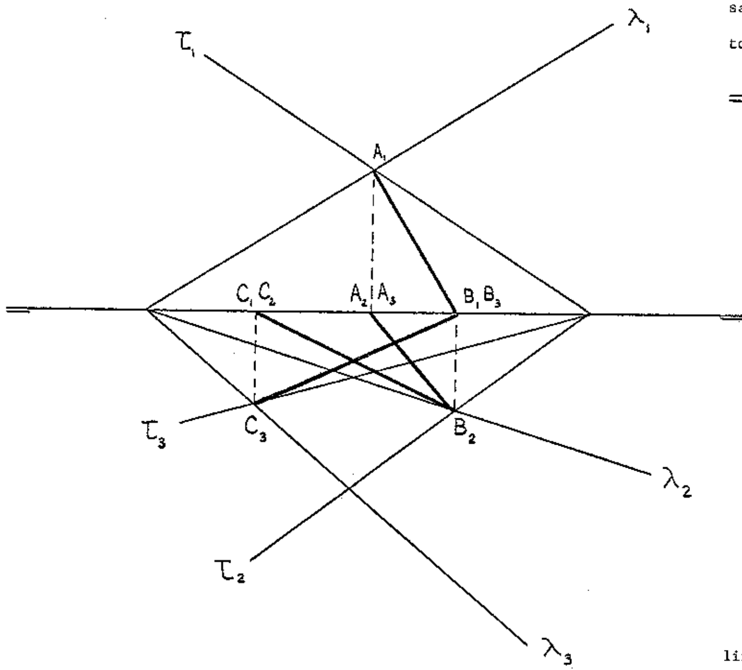


Space perpendicular to Σ_1 | Space perpendicular to Σ_2 | Space perpendicular to Σ_3

2. Intersection of two spaces.

This problem is always possible, for both planes belong to the same space of four dimensions.

The intersection is a plane. This plane is determined by two lines, intersections of four planes, two of them belonging to one of the spaces and two to the second space.



Intersection of the spaces T and Λ.

The space T is determined by the plane of τ_1 and τ_2, and the plane of τ_2 and τ_3.

The space Λ is determined by the plane of λ_1 and λ_2, and the plane of λ_2 and λ_3.

The intersection is the plane of (AB) and (CD), obtained as follows:

(AB) is the intersection of the planes τ_1 τ_2 and λ_1 λ_2.

(CD) is the intersection of the planes τ_2 τ_3 and λ_2 λ_3.

These two lines are concurrent in the point (B); they determine a plane that belongs to both spaces.

3. Observations.

The conditions of parallelism and perpendicularism between two spaces can be established in a similar manner, as is done in the study of the descriptive geometry of three dimensions.

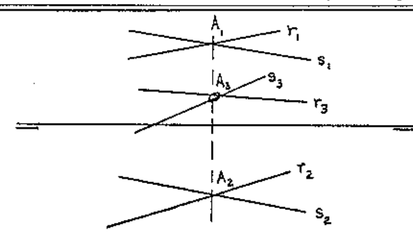
The problem of the determination of the intersection of a line and a space follows also similar steps as the determination of the intersection of a line and a plane in descriptive geometry of three dimensions. It is a problem always possible. However, the intersection of a line and a plane, in descriptive geometry of four dimensions, may not be possible.

REPRESENTATION OF THE PLANE

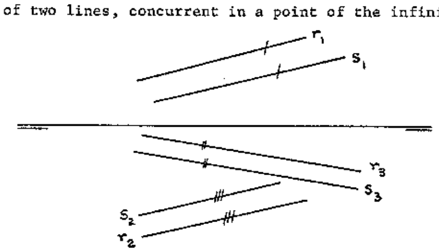
Two concurrent lines, in an objective point or in a point of the infinity, determine a plane.

When the two lines are concurrent in a point of the infinity, there is, when they are parallel, the projections of the lines on the same space of projection are parallel. Such a particularity is easy to demonstrate.

a. Plane of two lines, concurrent in an objective point.



b. Plane of two lines, concurrent in a point of the infinity.

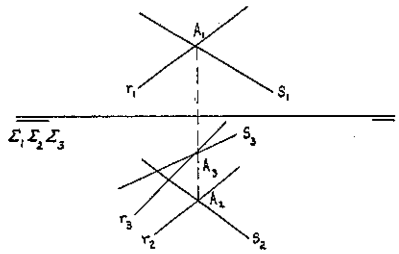


A plane belonging to a space T, does not have more than one line in each space of projection. This was demonstrated previously. For this reason, the lines of the plane in each one of the three spaces of projection will determine in each one of the planes π_1, π_2, and π_3, one point.

Problem: determine the points of the plane of two concurrent lines in each one of the planes π_1, π_2, and π_3.

Solution:

Given:



a. Consider only the projections of the lines on Σ_1 and Σ_2; determine the points that belong to Σ_1 and Σ_2.

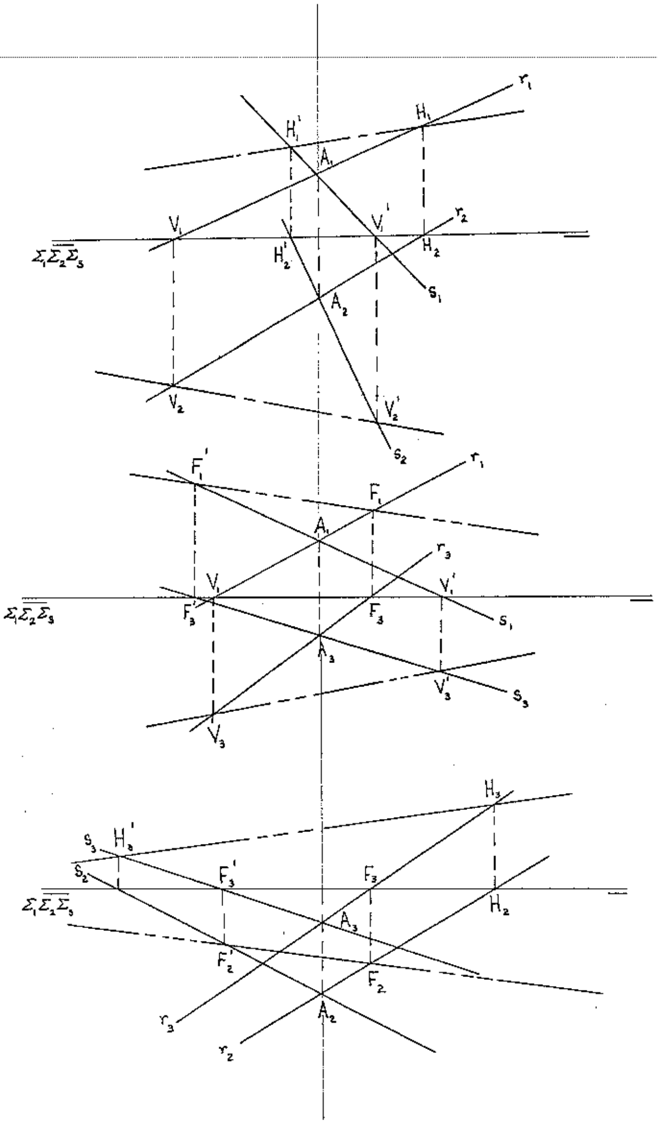
b. Consider only the projections of the lines on Σ_2 and Σ_3; determine the points that belong to Σ_2 and Σ_3.

c. Consider only the projections of the lines on Σ_1 and Σ_3; determine the points that belong to Σ_1 and Σ_3.

In the epure showing all three projections of each line, considering the line which projections are $H_1^1 H_1$, $V_2 V_2^1$, $V_3 V_3^1$ or $H_3 H_3^1$, we obtain the point of the plane on π_3, for the two first projections belong to the same point on the ground line.

Considering $F_1 F_1^1$, $V_3 V_3^1$, $V_2 V_2^1$ or $F_2 F_2^1$, we obtain the point of the plane on the plane π_2.

Considering $H_3 H_3^1$, $F_2 F_2^1$, $H_1 H_1^1$ or $F_1 F_1^1$, we obtain the point of the plane on the plane π_1.



Problem: demonstrate that two planes that do not belong to the same space, have only one point in common.

Solution: planes α and β are given.

Each plane belongs to different spaces. The intersection of the spaces is a plane γ, which is concurrent with the given planes, for α and γ belong to the same space T and β and γ belong to the same space Λ. The lines of intersection (AB) and(CD) belong to the plane, and for this reason they are concurrent in a point (S). This point is the only one that belongs to both planes α and β, for the plane γ that belongs to it is the only one obtained in this process.

Problem: demonstrate that a line and a plane that do not belong to the same space, do not have a point in common.

Solution: line "r" and plane α are given.

To determine the intersection of a line and a plane, we consider a plane β that contains the line "r"; determine the line intersection of α and β; the intersection of this line with "r" is the intersection of the line "r" with the plane α. In this case, however, the plane β that belongs to "r", determines with α one point, (A). This point (A) belongs to a plane that contains "r". To say that (A) belongs to "r" is an absurd, for they would determine a line and not a plane β

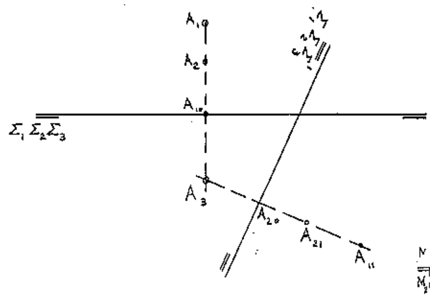
METHODS OF THE DESCRIPTIVE GEOMETRY

1. Change of spaces of projection.

When we change a space of projection, the two other spaces being kept in a fixed position, the distance from a point to these two spaces remain constant. Also, as a consequence, two of the planes that determine the spaces of projection change of position. During the change we should consider the projections of the point, two by two, as being made on the planes π_1, π_2, π_3. One of these projections remains the same after the process, and the change of one space only, is characterized by a new ground line, one fixed projection of the point, and a new line of recall from the fixed projection. On the line of recall, the distances to the spaces not changed are marked from the new ground line.

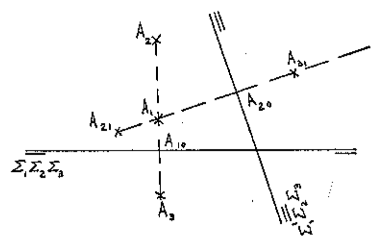
1.a. Change of the space Σ_3.

$A_{10} A_2 = A_{20} A_{21}$ and $A_{10} A_1 = A_{20} A_{11}$



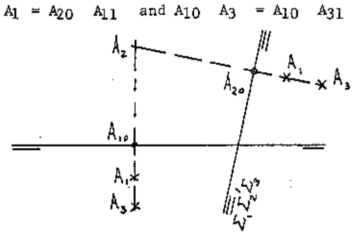
1.b. Change of the space Σ_1.

A_{10} A_2 = A_{20} A_{21} and A_{10} A_3 = A_{20} A_{31}



1.c. Change of the space Σ_2

A_{10} A_1 = A_{20} A_{11} and A_{10} A_3 = A_{10} A_{31}



Problems:

a. Given a point, change one of the spaces of projection so that the point will belong to one of the spaces.

b. Change the spaces of projection so that a given point will belong to one of the planes π_1, π_2, or π_3.

c. Change one of the spaces of projection so that the point will have two projections symmetrical in relation to the ground line.

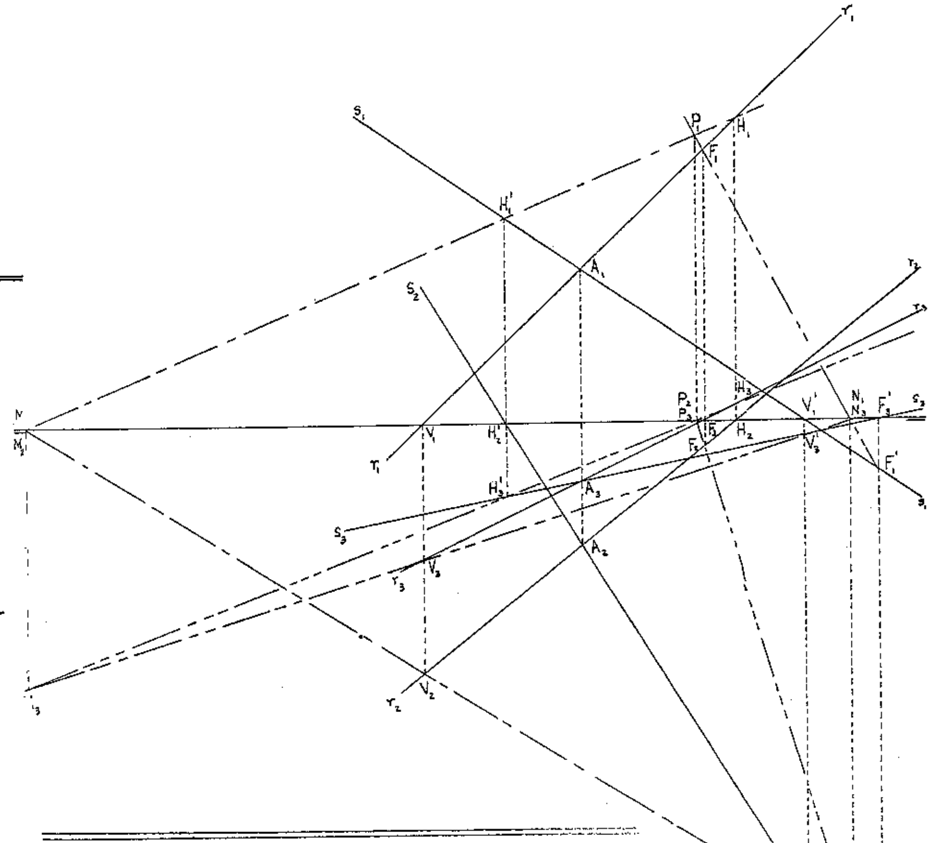
d. Change one of the spaces of projection so that a line will belong to one of them.

e. Change one of the spaces of projection so that a line will have two projections coinciding after the change.

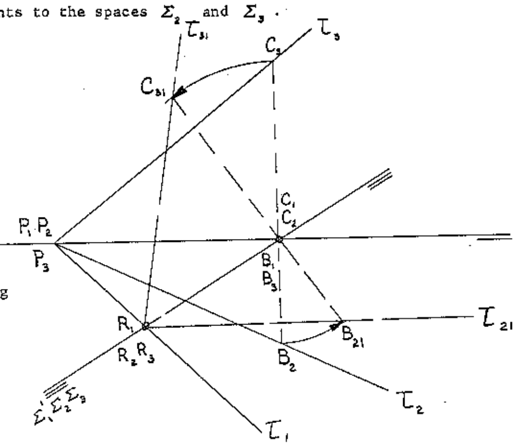
For the change of space of projection for space we shall consider the space determined by the planes intersections with the spaces of projection.

Given the space $\mathcal{T}$, the change of the space Σ_1 is made as follows:

- the position of the planes π_2 and π_3 change, but the plane π_1



remains fixed; the intersection of the space with π_1 is the same in the new system of reference; the projections with index 1 are the same; on the new line of recall from these projections, mark the distances from the points to the spaces Σ_2 and Σ_3.



Problems:

a. Given a space, make one change of space of projection so that the space will be perpendicular to one of the spaces of projection of the new system of reference.

b. Given a space, make one change of space of projection so that the space will be parallel to one of the spaces of projection of the new system of reference.

c. Given a space, make change of spaces of projection so that the space will be parallel to one of the planes that determine the spaces of projection in the new system of reference.

d. Determine the space that belongs to a given point and is parallel to a given space.

Solution of problem "d".

Two parallel spaces determine with the planes π_1, π_2 and π_2, lines parallel.

Call $\mathcal{T}$ the given space and (A) the given point.

Take a space Ω parallel to one of the spaces of projection, for example Σ_1. Find the intersection of the spaces Ω and $\mathcal{T}$ Call the plane intersection α, determined by the lines (MN) and (MP).

By the point (A) draw a plane parallel to α. This plane is determined by (AS) and (AR).

We verify that $A_2 R_2$ and $A_3 R_3$ will be concurrent on the ground line, if there is proportionality between the distances from the point (A) to Σ_2 and to Σ_2 and the distances from the point (N) for example, to the same spaces.

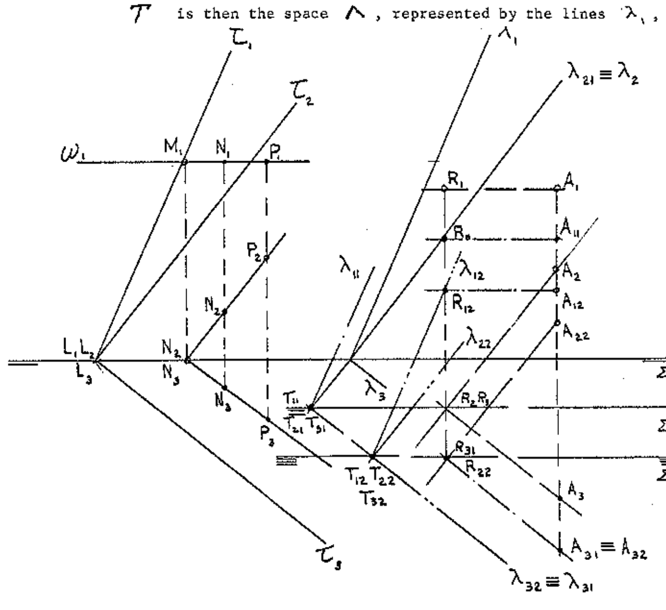
To obtain such proportion, make two changes of spaces to place the point (R) on one of the new planes, in the case the plane π_1''.

The first change, places the point (R) in the space Σ_2. The change is of space Σ_2.

The second change, of space Σ_3, places the point on the space Σ_3. The point has now the projections R_2 and R_3 on the ground line; belongs to the plane π_1''.

In this situation, the point (R) is a point of the intersection of the space with the plane π_1''. We can determine the three intersections of the space Λ with the three planes of the last system of reference. Since there is one line common to the systems, we determine the intersections of the space with the planes π_1, π_2, and π_3 of the second system. From this system we determine the intersections of the space with the planes π_1, π_2, and π_3 of the original system of reference.

The space that belongs to (A) and is parallel to the space $\mathcal{T}$ is then the space Λ, represented by the lines λ_1, λ_2, and λ_3.

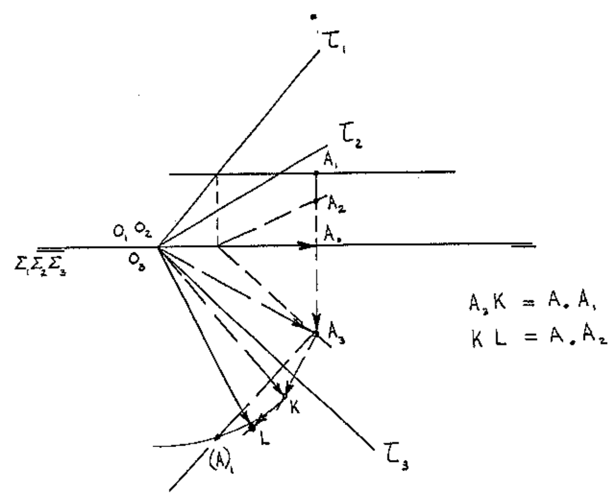


2. Rabattement.

The problem of the rabattement of a plane, can be solved by the same manner as is done in the descriptive geometry of three dimensions. The plane that belongs to a space, will rotate about the intersection of the space that belongs to it, with a plane parallel to one of the planes π_1, π_2, or π_3, until both planes coincide.

If the space is given by the lines intersections with π_1, π_2, and π_3, a point of the space rotates about the intersection with the plane on which the rabattement is being made.

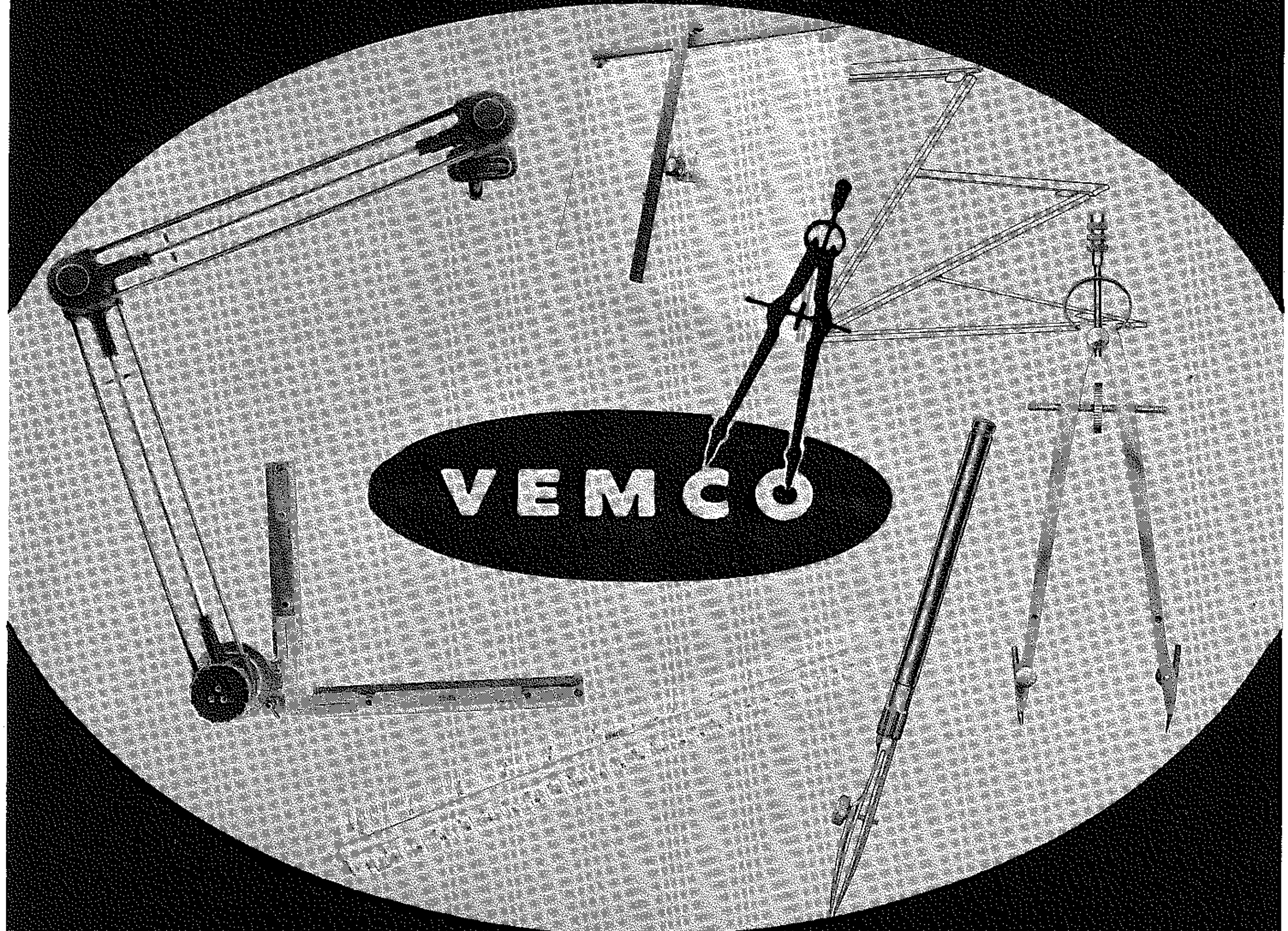
The rabattement of the point is located on the perpendicular drawn from the projection of same index, to the axis of rotation. The problem is to find out the location of the point on the perpendicular. This is determined by making a vectorial addition of the coordinates of the point in relation to the point of the space that belongs to the ground line. We will determine then, the distance from the point in the space of four dimensions to the point on the ground line. After the rabattement this distance remains the same. With center on the point of the ground line and radius equal to the distance determined, cut the perpendicular in a point that is the rabattement of the given point.



Problems:

a. Determine the true value of the sides of the triangle determined by three points of a plane on each one of planes π_1, π_2, and π_3.

b. Determine the plane angle between the intersections of a space with the planes π_1, π_2, π_3, and the dihedral angle between the planes intersections of a space with the spaces Σ_1, Σ_2, and Σ_3.



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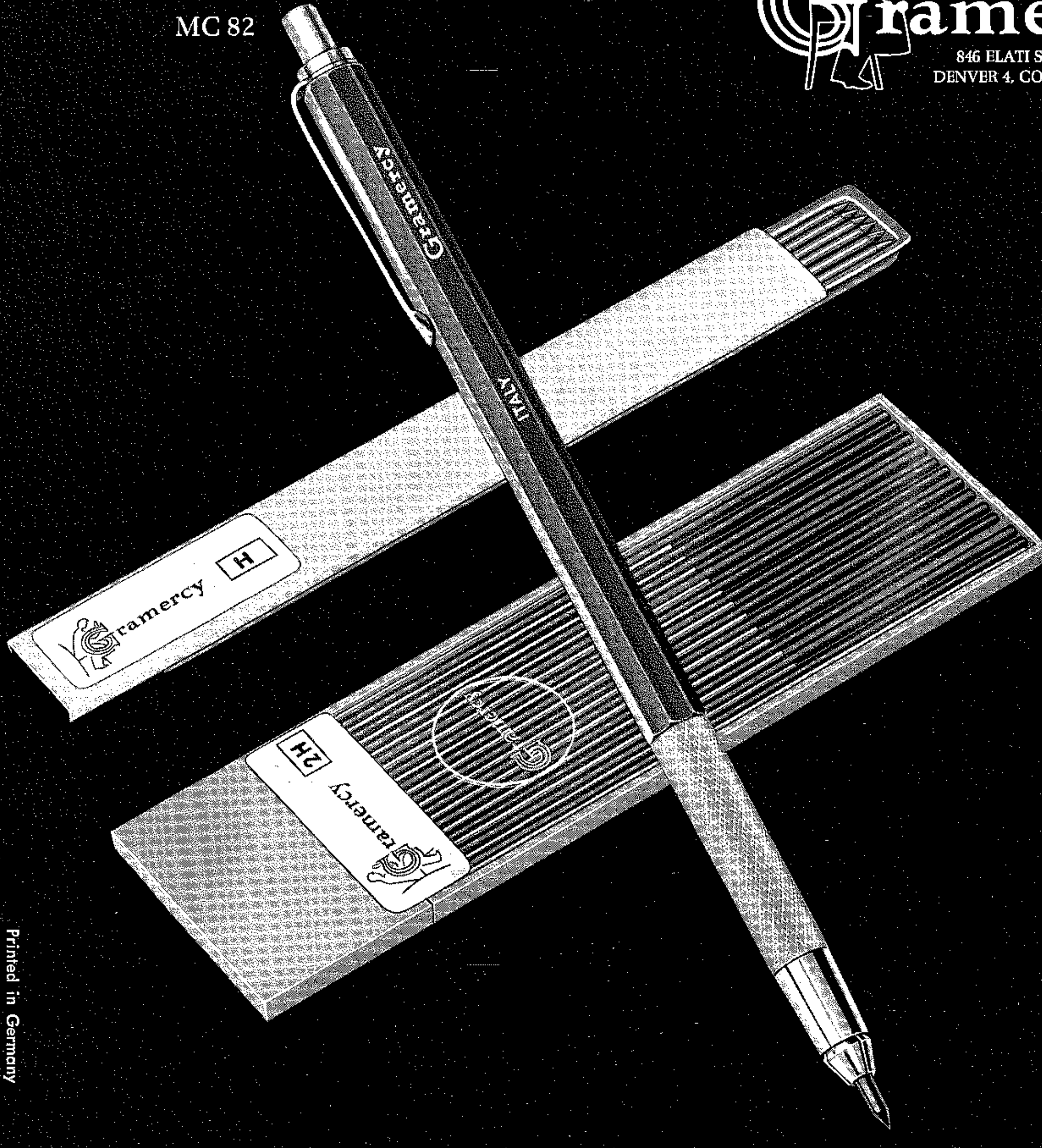

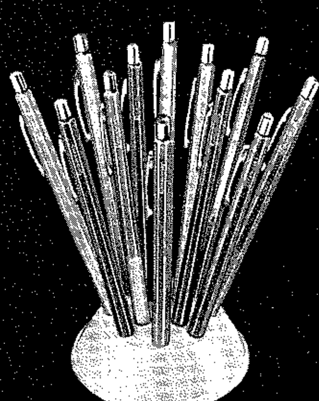

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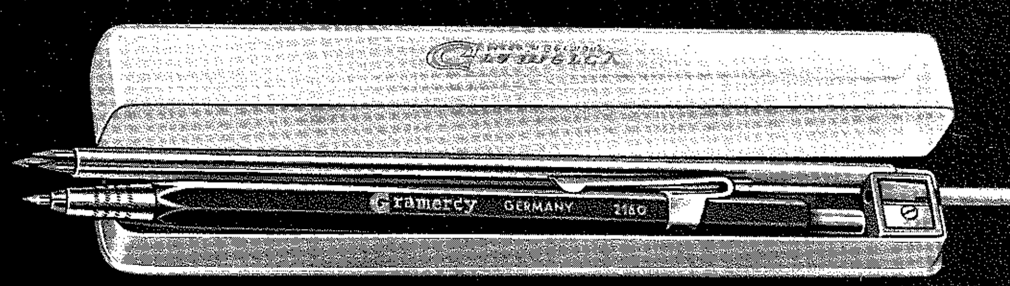

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