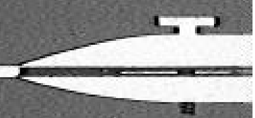
THE JOURNAL OF ENGINEERING GRAPHICS



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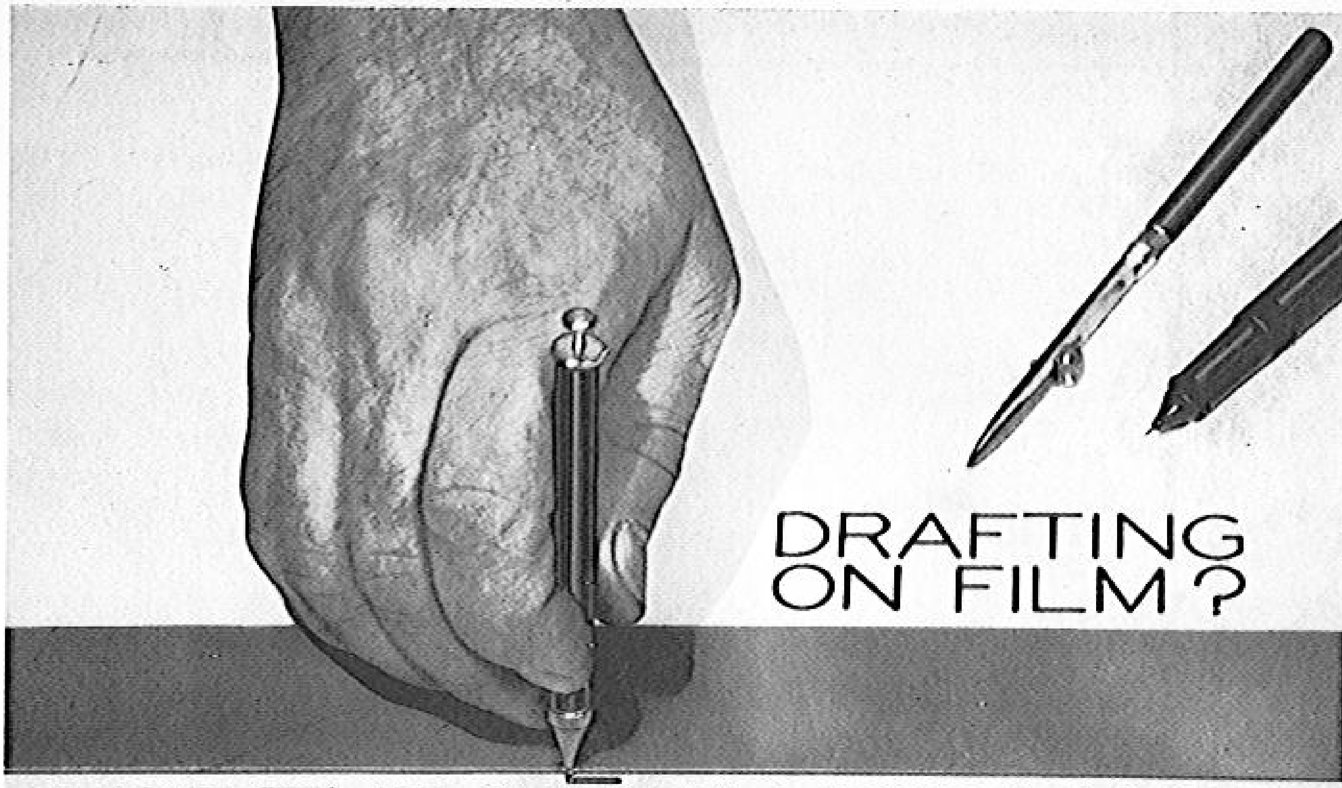

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In this issue of the Journal of Engineering Graphics you will find stimulation for better teaching, new materials for the advanced use of graphics, and news about the important Graphics Course Content Development Study. Our friend "Vlad" ends the Journal with an editorial comment which gives us a warning not to be seduced by frills and embellishments of nomograms & graphical calculus which will divert us from out primary teaching mission and the concepts of descriptive geometry engineering drawing.

Amid the hustle and bustle of curriculum revision which is going on at most engineering schools today I would like to call for a comprehensive study of national needs for engineering graphics, engineering drawing and drafting as practiced at all levels, whether as an aid to conceptualization in the mind of an engineer or as the ability to make a sketch or to make a complex drawing on the board.

A few engineering schools now have no engineering graphics courses. The implication of this type of revision of engineering curriculum should be studied in terms of its national consequences.

At present the engineering schools of this country enroll about 60,000 freshmen of whom more than half fail to graduate in engineering. Until recently all engineering schools required instruction in engineering graphics in the freshman year. This means that there have been in addition to 30,000 engineering graduates, about 30,000 men every year who, although they did not graduate in engineering, have some knowledge of the principles of orthographic projection, solution of space problems, dimensioning, and at least the rudiments or preparation of engineering drawings.

Any change in engineering curriculum should therefore be considered not only for its implication for the engineering graduate but also for those who enroll but fail to graduate. The idea of curriculum review for the ultimate benefit of all students, whether they complete the course or not is a radical innovation. It means that we should be reviewing curricula not only in terms of that touted "whole man" who manages to graduate but also in terms of the whole society which is made up also of the "school-leavers".

Professor Wayne Schick of the University of Illinois has been making an interesting study of the number of persons who have potential ability as designers and draftsmen. He has found that there is a steady and significant decline in the number of such persons. There are several factors contributing to the decline. Probably the most important is that the number of young people electing to study engineering is declining. Another factor is that more engineering graduates are extending their schooling and studying advanced programs in science and engineering and therefore are not available for employment during these years.

When Professor Paul Reinhard with the cooperation of the Division membership completes the study of course content of graphics on a college level, the Division should undertake a national study of manpower resources in engineering graphics and related abilities. Such problems as the effect of college curriculum changes, technical institute and high school training, and the changing needs of the country for talents in graphics should be studied in relation to the role of graphics instruction in engineering colleges.

Are there any volunteers interested?

Mary Blade

Mary Blade, Editor

P-H

PUBLICATIONS

Basic Graphics

by WARREN J. LUZADDER, Purdue University

BASIC GRAPHICS, the New edition of *Graphics for Engineers,* is designed to fulfill today's needs of engineering and technical education. This text presents the fundamentals essential to graphical solutions and communications. Each basic concept is discussed clearly and in detail, anticipating difficulties commonly encountered by the student.

BASIC GRAPHICS features: freehand drafting and pictorial sketching — three new chapters — revised material on multiview representation and conventional practices — expanded coverage of descriptive geometry, engineering geometry and graphical calculus — larger page size — and new reproduction plates of both old and new illustrations.

1962 — *715 pages* — *Text price: $9.75*

Fundamentals of Engineering Drawing, 4th

by WARREN J. LUZADDER

Designed for the beginning student, this book is based on a "self-teaching" approach that makes it uniquely easy to use as a guide through all phases of engineering drawing, regardless of the student's background knowledge. This time-tested approach, proven through years of usage with students of all levels, incorporates the ASA and SAE standards and practices to provide the student with a solid basis for understanding.

The author lucidly presents the use of instruments, lettering, engineering geometry, and multiview drawing. He carefully follows with the all-important tool of any trade — language. Upon this bedrock foundation, subsequent knowledge and understanding are built throughout the text.

1959 — *720 pages* — *Text price: $8.75*

Problems in Engineering Drawing, 4th

by W. J. LUZADDER and J. N. ARNOLD, both at Purdue University, and F. H. THOMPSON

A manual of laboratory practice material written specifically to accompany *Fundamentals of Engineering Drawing, 4th.* It may be used with equal effectiveness to parallel other standard textbooks. Solutions free upon adoption.

1959 — *72 sheets* — *Text price: $3.95*

For approval copies, write: BOX 903

PRENTICE-HALL, INC.

Fundamentals of Engineering Graphics

by MYRON G. MOCHEL, Clarkson College of Technology

A stimulating text for courses in your modern engineering curriculum — bringing the field of graphics into line with the latest trends in engineering instruction. Prepared by an engineer of many years' teaching and professional experience, this text represents a unique, class-tested approach. It emphasizes freehand drawing as a means of communication and offers a wealth of engineering problems for student solution. The book has been designed to coordinate with concurrent courses in mathematics and physics.

1960 *379 pages* *Text price: $8.50*

Elements of Descriptive Geometry, I and II

by LEWIS O. JOHNSON and IRWIN WLADAVER, both at New York University

Here is a book that offers the future engineer the basic material to help him direct the work of others and help himself put his own ideas into tangible form. Stressing underlying principles, the book familiarizes the student with the equipment he will need to understand and interpret what he sees on a blueprint. Part I includes the textual material with numerous illustrations. Part II provides over 70 problems. The two parts may be used together or separately — with any other workbook or text.

Part I: 1953 *75 pages* *Text price: $2.25*
Part II: 1953 *71 problems* *Text price: $4.50*

E. I. T. Review

by VIRGIL M. FAIRES, U. S. Naval Postgraduate School, and JOY O. RICHARDSON, California State Polytechnic College

For students preparing to take their state registration examinations for Engineering-In-Training, here is a complete review in one volume. It offers the primary technical subjects of the undergraduate engineering course. The book includes mathematics through Calculus, kinematics, statics, thermodynamics, short statements of scientific laws, typical problems, and examples taken from state engineering registration examinations throughout the country. May be used in both class instruction or for self-study.

1961 *256 pages* *Text price: $6.75*

Englewood Cliffs, New Jersey

A Backstage of Genius

By Kenneth E. Lofgren

What's the difference between a product that displays creativity and one that doesn't? How do we rocognize it when we see it, and what's the difference between a person who is creative and one who isn't?

These are some of the questions that bother many of us and unfortunately there are no absolute answers. There are degrees of creativity, and by and large, every person from a baby upwards displays evidence of it. Children invent games and toys; students invent schemes to dodge work; professors devise diabolical problems to excite the thinking processes of their students, and all of us manage somehow to solve many intricate problems by being creative.

As educators, we try to bring out the creativity in our students, be our classes in art or in engineering. We thrill to solutions which we claim display originality -- others fail to stir us. Of the latter we say the solutions are humdrum, imitative, uninspired. Undoubtedly all of us have the necessary perspicacity to tell the difference. We generally recognize the bizarre, the unusual, the really "nifty" solutions.

Narrowing our thoughts now, to considerations of design we might well ask: Is it necessary for a solution to be bizarre, or unusual or complex in order to stir us? If an ordinary screw will serve adequately to hold two pieces together, wouldn't it be silly to hunt for other schemes -- just for the sake of providing uniqueness?

If the goal sought is nothing beyond uniqueness, then probably we are indulging in a questionable luxury. But suppose our aim is to reduce production costs. One has only to compare electronic equipment made today with the radio sets made thirty years ago to get a striking answer. Then, almost every component was fastened down with numerous nuts and screws (to the delight of those who loved to tinker). Today, rarely does one find screws and nuts in such equipment. In their places we see cheap rivets, bent-over tabs, staples, parts crimped together with simple grammets, interlocking schemes, and many other stunts which cut down production costs. The switch from screws in many cases entailed much creativity. This implies that creativity, in order to be desirable, must serve a useful purpose. Frequently it is needed in order to produce devices which can compete with those already on the market without infringing c patents and copyrights.

Who is creative beyond other people? Can we spot this ability in our students? Certainly we can; it's right there for us to see, and there are many signs. In order to be creative, a person must want to be, and it must not be merely an idle wish. He must work at it. Artists, musicians, writers, all bespeak an inner urge -- frequently a fury -- which burns within and clamors for release in the form of a masterpiece. Engineering design hardly begets frenzy of this sort, but something related to it is nevertheless a factor.

The creative student (a future design engineer), has a deep searching curiosity to find out how things work. He's the boy who makes a pest of himself at exhibits and demonstrations with his mass of meaningful questions. Frequently he displays more knowledge of the exhibit than the booth attendant. When this brash individual graduates from an engineering school he has already amassed a formidable and valuable substitute for actual professional experience. Because of his persistent search for answers his brain is a storehouse loaded with concepts of mechanisms, kinematic chains, gear trains, as well as an intimate knowledge of force, friction, velocity, acceleration, mass inertia, thermal and electrical relationships, and electronics.

Another facet of this picture of the creative engineer, is to my mind, of extreme importance. I have never seen a person skillful in design who was not also skillful with his drawing pencil, particularly in freehand sketching.

While to a small degree I was involved in the following story, I was not present at the actual birth of an idea which solved a critical problem in aerial photography some years ago. This nonobstetrical delivery occurred, of all places, in a church while my co-worker Frank was supposed to be paying devout attention to his pastor's sermon.

In those days we did not have the fine grain photographic film available today, and in order to get the detail needed for aerial mapping at altitudes up to 40,000 feet we had to have massive cameras with focal plane areas as large as an opened tabloid newspaper. The problem of keeping the film flat against the back plate was nicely solved by making this plate hollow. Drilled through the optically flat surface of the plate were hundreds of small holes leading into the opening inside the plate. A hose connection to this opening then led to a Venturi tube held in the slip stream of the airplane. This provided a vacuum which sucked the film tightly against the focal surface. Cameras of this size were not held in the hands of the photographer but were mounted in suitable frames anchored to the plane. They were massive and awkward anyway, and the encumbrance of the Venturi tube and attendant hose line were accepted, although bothersome, adjuncts.

For smaller and more portable cameras (large by today's standards), this solution was not practical and simpler means were sought. Frank had been placed in charge of the design of a new line of smaller cameras and again the problem of flatness arose. The usual method of relying on tautness of the film was quite unsatisfactory. Frank kept saying that someday somebody was going to make a "killing" with a novel device.

And so, he was in church -- and restless. His fretting could be eased only by having pencil and paper in front of him, so out came his little notebook and pencil.

Let's see. He mused. How do we get a vacuum? A vacuum tank? That's no better than the Venturi -- tubes all over the place and a big can besides. No good.

His pencil drew a rectangle. Suddenly it became a cylinder with a piston inside. A pump! He thought. Well, why not? We could have a cylinder right inside the camera. Maybe it wouldn't have to be so large.

But how do we drive it? Can't expect the photographer to move it manually. Those prima donnas; they just wouldn't do it. It'd be simple though. All it would need would be one push -- one push for each picture. Even so, we can't ask them to do it. Forget to do it just once and a whole flight might be ruined. Could we have the shutter button push the plunger? No. Not fast enough, and it would need a real fast snap; like a spring would give it. Wait! A spring! Sure, of course. The spring could be energized in the film wind-up. The photographer has to do that anyway, and that's something no pro would ever admit forgetting. Then when he snaps the shot, automatically the spring lets go and we get our vacuum.

But what about timing? Will the vacuum come on in time for the shot? If we increase the stroke length of the snap button, we can make it release the spring before the shutter trips.

Now to get the maximum vacuum effect we better put the cylinder smack up against the back plate in order to keep the connecting tube real short. By golly! Let's do away with all tubes -- we'll make the cylinder integral with the back plate itself.

"Eureka!" He cried out loud. "I've got it!"

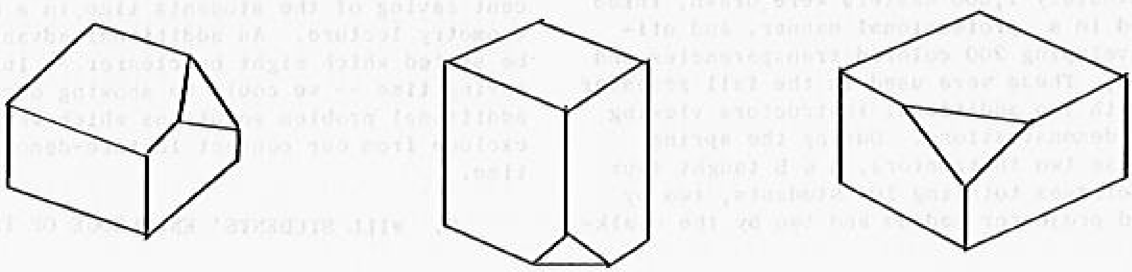
To give an idea of how compact the final result was, the bore of the cylinder was eight inches in diameter but the stroke was only one quarter of an inch in length. The cylinder was nothing more than a shallow recess in the focal plate, and surprisingly, only moderate precision machining was required, The duration of the suction effect never needed to exceed one quarter of a second.

What are the "behind the scenes" factors in this little tale? Frank brought a vast mental library to this problem. First of all he knew like few others the intimate details of camera design. His brain was crammed with release devices, dedents, ratchets, delayed motion mechanisms, and countless other gadgets that are found in complex cameras. Second, he had been living with this problem for a long time. Undoubtedly a part of his subconscious mind was approaching a coup de maitre. Then too, his skill in visualization, and in putting on paper with magic lines, the fruit of his brain, made the brilliant solution almost inevitable.

One finds creativity in many places, in many people, but while wild flowers grow in rude fields, the flowers that win prizes for exquisite beauty are those on which endless toil and care have been lavished. We who are graphics and design teachers have an opportunity to till the soil of genius which lies in many of our students. Like many professors who have had hundreds of students, I receive numerous visits by graduates who enjoy showing me some particular design achievement of which they are justly proud. Frequently, I am forced to comment --"I don't believe I could have worked that out." But then, after all, one doesn't expect the gardener to be as beautiful as the rose.

PROBLEM IN DESCRIPTIVE GEOMETRY

Assume you have a box which is 6 inches wide, 10 inches high, and 5 inches deep. The lower right forward corner is to be cut off so that the corner edge on the 6 x 10 face is 4 inches long, the corner edge on the 6 x 5 face is 3½ inches long, and the corner edge on the 5 x 10 face is 3 inches long. Draw the box with the out corner in two adjacent views. Send your solutions to the Editor. First and best received will be honorably mentioned in the November 1962 issue. (Editor's note: this is really a device to find out when you receive the May Journal. This issue is being sent to press today, April 2, 1962. If Circulation Manager Bob LaRue is circulating on time and he has no trouble with his IBM machine you should receive this journal on the first of May.)



TEACHING ENGINEERING GRAPHICS WITH COLORED TRANSPARENCIES--AN EVALUATION

By Clayton W. Chance, Assistant Professor of Drawing University of Texas, Austin, Texas

The research reported herein was supported by a grant from the United States Office of Education, Department of Health, Education and Welfare

Engineering Descriptive Geometry courses are taught by the lecture-demonstration method together with supervised laboratory work. The many drawings made now on the chalkboard should be skillfully constructed, visible to all students and competently explained. Objections to this method are: 1) teacher has his back to the class; 2) figures on the board are too small to be seen by all students; 3) time required for making drawing limits the amount of material covered; 4) most teachers use white chalk, thereby only one color is viewed.

A 15 month research study recently completed at the University of Texas proposed that approximately 200 drawings with some 800 accompanying overlays required in the lectures for one semester in Descriptive Geometry be made in a professional manner on colored transparencies and projected onto a screen by means of the Overhead Projector. These transparencies show a specific problem setup, then progressive overlays reveal subsequent steps in different colors leading to an ultimate solution to each problem. A large image at a short screen distance in a semi-darkened room permits use of the projector in front of the class, thus enabling an instructor to face and speak directly to those in attendance. This will lead to more effective teaching and handling of larger lecture groups of students.

This new method of presenting lecture-demonstrations used in teaching Descriptive Geometry, when placed at the disposal of an "average" teacher (young or otherwise), will increase the effectiveness of his classroom lectures and chalkboard demonstrations many fold. This course is taught to all second semester Freshmen Engineering students and lectures contain numerous type problems, illustrated on the chalkboard utilizing basic fundamentals. Effectiveness of chalkboard demonstrations is materially affected by the skill of a teacher in making them. Therefore, by adopting the Overhead Projector-transparency method of teaching, an "average to good" instructor will be much more capable of becoming an "excellent" teacher in presenting subject matter in a more interesting, better organized and understandable manner.

Five OBJECTIVES were setup at the beginning of this research study and these questions will be discussed one by one in this paper today.

Approximately 1,000 masters were drawn, inked and lettered in a professional manner, and utilized in developing 200 colored transparencies and 800 overlays, These were used in the fall semester last year with two additional instructors viewing the lecture demonstrations. During the spring semester these two instructors, A & B taught four controlled classes totaling 104 students, two by the overhead projector medium and two by the chalkboard method. These classes were made up at registration. Organized on a random basis as equally as possible with the teaching method being the only known variable. Results on a student questionnaire and Form A of the Space Relations Differential Aptitude Test were used by Instructors A & B and myself in setting up a vertical rating scale with the rank of each student in the two sections of the combined controlled classes. After completion of this ranking from top to bottom, a distribution into the "transparency" or "blackboard" class was accomplished by purely random casting of the lot. Daily information on these four classes was tabulated covering some 10,700 daily drawing grades, 500 quiz grades, 100 final exam grades and 100 final course grade averages.

It was originally the responsibility of the project director (myself) to set forth answers to the objectives of this research study. Because it was felt that answers would have a stronger significant value if the opinions of the two instructors were taken into account, they were consulted in the organization of the following and agreed in essence with their wording.

1. CAN THE LECTURE-DEMONSTRATION PERIOD BE REDUCED SO AS TO ENABLE THE STUDENTS TO EXPERIENCE LONGER SUPERVISED LABORATORY PERIODS?

If the amount of lecture material being viewed by students could be kept equal for comparison purposes, the transparency medium would very definitely provide a shorter lecture period. I utilized a stop watch while visiting several lectures of both media. This revealed an average of 5 minutes <u>per lecture</u> longer duration for the blackboard over the transparency lecture. This period of 5 minutes would be even longer if the instructors would have covered an equal amount of demonstration material on the blackboard that was already prepared for viewing on the colored transparencies. Also, it was felt in the transparency lectures too much problem construction detail was pointed out by the instructors. After instructors become more familiar with the transparencies, overall lecture time in the transparency class could be reduced, hence allowing even <u>more time</u> for a longer supervised laboratory period. I believe an average approximated figure of 10 minutes per 50 minute lecture could be saved by the transparency medium over a comparable blackboard lecture which (if my slide rule didn't slip) would amount to a 20 percent saving of the students time in a Descriptive Geometry lecture. An additional advantage could be stated which might be clearer -- Instead of saving time -- we could be showing our students additional problem solutions which we have had to exclude from our contact lecture-demonstration time.

2. WILL STUDENTS' KNOWLEDGE OF THE

FUNDAMENTALS INVOLVED IN PROBLEM SOLUTIONS BE INCREASED?

This objective with reference to the student's daily work can probably be answered best by comparing class averages over the daily drawing grades which is a measurement of drafting skills and five quiz grades which measures the effect of learning. The transparency group average was 83 percent compared to the blackboard group average of 81 percent, a difference of 2 in favor of the transparency medium. In comparing group averages for the five quiz grade totals, the transparency group averaged 78 percent to a 75 percent for the blackboard, a difference of 3 percent in favor of the transparency group. Although neither of these differences is large enough to be statistically significant, both of them are in the same direction--i.e., in favor of the transparency group.

In comparing group average for the Final Examination Grade, which supposedly measures retention, the transparency group averaged 76.9 percent in contrast to a 71.2 percent for the blackboard group. This figured a 5.7 percent differential in favor of the transparency group. In comparing group averages for the Final Course Grade which is indicative of a student's level of attainment of Descriptive Geometry, again the transparency group led the blackboard group, 79.3 percent to 74.9 percent. This supplied an average differential figure of 4.4 percent or practically a one-half grade point betterment.

Both of these differences were statistically significant at the .05 level of confidence.

3. WILL THERE BE MORE TIME DURING THE LECTURE FOR THE STUDENTS TO ASK ADDITIONAL QUESTIONS?

From answers supplied for number one objective, it has been ascertained that according to the clock there <u>is</u> more time available <u>if</u> the students wish to ask additional questions <u>and</u> indulge in class discussion for the purpose of a better understanding of problem solutions. A random selection of various lectures along with a tabulation of total number of questions asked in each of the two media groups, reveals a surprising fact. Of the total number of questions asked in these lectures, 70 percent were in the transparency group. One idea which I may express in trying to supply a reason for this fact, is that the transparency medium provides an easier way for an instructor to teach this subject. Therefore, psychologically students feel that problem solutions are easier to understand, hence, their attentiveness is greater and they realize sooner when a question comes to mind.

4. SHALL THE FACULTY PREFER TO ENGAGE IN TRANSPARENCY DEMONSTRATION IN CONTRAST TO THE TIME PROVEN CHALKBOARD DRAWINGS?

Before any instructor can express an opinion on this objective, he must actually experience for himself this newer method of teaching by utilizing an overhead projector and colored transparencies. Observation of another instructor using this medium is not convincing enough. Because of contrasting differences involved, an instructor should teach more than one class before he starts feeling at ease with the transparency medium approach. I have used this in four of my classes this past school year and found several techniques which could be used after familiarity was gained with the projector, semi-darkened room, transparencies and projection screen. Both Instructors, A & B thoroughly enjoyed the experience of using this transparency medium and after observing the final results of this research project join with me in an affirmative vote in favor of the transparency method of teaching Engineering Descriptive Geometry. One additional factor in favor of the transparency medium approach to teaching was voiced by several faculty viewing this research project, that it allowed for a more professional appearance to lecture demonstrations. This fact is one which I personally subscribed to and presume that many of you agree, that at all levels of teaching, we teachers on a national scale must gain a more professional stature.

5. AFTER COMPARING STUDENTS IN FOUR CONTROLLED CLASSES, WILL THERE BE A NOTICEABLE IMPROVEMENT IN THE FINAL GRADES OF THE TWO TRANSPARENCY TAUGHT CLASSES VERSUS THE TWO CHALKBOARD TAUGHT CLASSES.

As indicated earlier in this paper, students that participated in this project were ranked by we, three instructors on a vertical rating scale and distributed into four equal sections. These were then cast into a transparency or blackboard group by the toss of a coin. A later review of the Space Relations Pre-Test scores indicated that the four classes started out at the beginning of the semester with as even a distribution as could be expected. All known variables were taken into account, namely, a) difference in instructors, b) difference in scheduling time of classes, and c) difference in teaching methods. At the conclusion of the course, and after final grades were tabulated, graphs were compiled which showed comparisons of the two teaching methods in each of the grade categories.

GRAPH I

COMPARISON BETWEEN TRANSPARENCY AND BLACKBOARD TAUGHT CLASSES MEAN DEVIATIONS

MEDIA	SEC.1	SEC.5	SEC.7	SEC.9	GROUP AVE.
Transparency	77.3		81.3		79.3
Blackboard		76.7		73.1	74.9

This graph supplies a comparison between the two media by class divisions. Sections 1 and 5 were taught at 8 o'clock and Sections 7 and 9 were taught at 10 o'clock. Instructor A taught Sections 1 and 9, Instructor B taught Sections 5 and 7.

GRAPH II

COMPARISON BETWEEN TRANSPARENCY AND BLACKBOARD TAUGHT CLASSES 104 STUDENTS

FINAL COURSE GRADES

MEDIA	A	B	C	D	F	DROP OUTS
Transparency	9	18	12	6	3	3
Blackboard	5	20	12	3	9	4

In this graph notice differences in the extreme ends of the grade scale. Of the total number of students that made an "A" in the course, 64 percent were in the transparency sections. Of the total number of students that made an "F" in the course 75 percent were in the blackboard sections. Notice in the middle grade scale (c) both mediums produced an equal number of students.

GRAPH III

COMPARISON BETWEEN TRANSPARENCY AND BLACKBOARD TAUGHT CLASSES-INSTRUCTOR A

FINAL COURSE GRADES

MEDIA	A	B	C	D	F	DROP OUTS
Transparency	4	7	8	3	1	1
Blackboard	3	10	6	2	5	0

GRAPH IV

COMPARISON BETWEEN TRANSPARENCY AND BLACKBOARD TAUGHT CLASSES-INSTRUCTOR B

FINAL COURSE GRADES

MEDIA	A	B	C	D	F	DROP OUTS
Transparency	5	11	4	3	2	2
Blackboard	2	10	6	1	4	4

Graphs III and IV allow for a comparison between Instructors A and B in the obtained Final Course Grade results. Note that both instructors had a better teaching effort utilizing the overhead projector transparency medium.

In conclusion, I wish to discuss some personal Recommendations which have stemmed from experience on this research project. If an individual has not experienced the use of an overhead projector, one should become familiar with it and gain experience not by observing, but by actually working with it.

One prime advantage as listed in advertising literature is the fact that it can be operated in broad daylight. Experience on this research study shows this somewhat of a false statement. Because of the nature of our Descriptive Geometry problems colored lines projected on the screen are washed out unless the room is darkened down approximately 80% of its broad daylight reading. This allows for deep color differentiation and a much more professional presentation.

This overhead projector is designed to allow the lecturer to stand or sit facing his class while at the same instant turning overlays or writing, sketching, or drawing on an acetate roll stretched over the projection light table. It is through this new approach that an instructor still feels this equipment is an aid and that he retains full control of his student audience regardless of class size.

Transparencies that are prepared previous to the lecture demonstration allow for two very important features to transpire. First, a much improved presentation in color over a blackboard-white chalk method will increase students' attentiveness many fold. Secondly, because students actually are not learning anything new while the instructor is drawing lines which form the end result, colored overlays indicate subsequent theoretical steps to a problem solution and save much of the students concentration time.

The audio-visual medium is based on three psychological bases which are especially important in education. They are 1) sight-mindedness, 2) reinforcement, and 3) repetition. The first of these concerns the fact that most of man's learning is acquired through a sense of vision. Authorities state that approximately 80 percent of our knowledge is acquired through eyesight while less than 15 percent is learned through a sense of hearing. In regards to retention of this knowledge, the following chart[1] should prove the necessity of not only speaking to the students but allow them to view problem solutions large enough so that all can "get the lesson."

GRAPH V

RATE OF RETENTION OF KNOWLEDGE LEARNED THROUGH TWO SENSES

Senses	3 Hours Retention	3 Days Retention
Ear	70 %	10 %
Eye	72 %	20 %
Ear & Eye	85 %	65 %

Through some nine years teaching experience, eight of them being in the area of college teaching, I believe that the present size of Engineering Drawing classes is based on three reasons -- 1) laboratory facilities have been controlled by the viewing size of a blackboard lecture section; 2) students of 25 or 30 are enrolled presently because it has been done that way for years without any known statistical research to back it up. 3) Since most drawing instructors feel that a good share of their students knowledge is gained thru grading, we have reluctantly pressured administrations for additional funds to pay student assistants.

Therefore, I recommend through experience gained on this research study, that formal lecture sections be enlarged to contain 75 to 90 students. This would be possible because of a large image controlled by the overhead projector and most important would automatically allow for better staff utilization of professional teaching personnel. This would not alter my present philosophy that a large share of teaching of this basic engineering subject is accomplished after the lecture in smaller laboratories of 20 to 30 students.

Lastly, I would like to list here the most outstanding advantages of this medium of communication. But first let's view a half dozen of our transparencies which I picked out of the teaching file. The transparency-overhead projector method of teaching is better than the blackboard-white chalk method because:

ADVANTAGES:

1. Larger viewing image-more professional presentation.
2. Addition of 6 colors.
3. Improves student attentiveness
4. Allows more time for students to ask additional questions.
5. Review fundamental steps to problem solutions by turning overlays easily.

As scientists and engineers are constantly searching for new and better ways to improve man's standard of living, we professional educators who are involved in the education of young minds in this curriculum area, must not dismiss newer teaching techniques which are beginning to gain national attention.

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[1] Taken from taped speech and prepared slides by Lloyd Trump, Director, Commission on Staff Utilization. Presented at the 1960 Worshop on Staff Utilization for Secondary School Principals, University of Texas.

PART II

TEACHING DESCRIPTIVE GEOMETRY WITH COLORED TRANSPARENCIES

In this article, information pertaining to the production schedule will be provided, along with an accompanying cost analysis which is necessary for anyone who wishes to devise a curriculum file of colored transparencies.

As the preceding article stated, approximately 1,000 drawings had to be drawn, inked and lettered before colored transparencies could be produced. During the summer of 1959 when the research grant financing this study was established, there was no literature available which described a similar problem. Therefore, it was decided that a production schedule and cost analysis would be maintained for future reference. These are tabulated here with the hope that after reading both articles other teachers will develop an interest in this medium of communication and will be able to raise the standards of lecture demonstrations in their areas.

PRODUCTION SCHEDULE

Following are tabulations and time sequence break-downs based on an average time limit of the steps which were followed in this study.

1. Drawings

New drawings were made covering each problem area of the curriculum. Upon completion of an accurate pencil master, a series of color separation sketches (CSS) were traced freehand off the master drawing. These were used not only to determine the series of overlays desired but indicated the exact information needed on each subsequent step of the overlay pattern and supplied the total number of overlays needed to explain each problem thoroughly.

Average Time Consumed:

Problem Sketch	First Layout	Master	C S S	Total
1/2	1 1/4	1	1	3 3/4

All figures based on hour readings.

Material:

Ozalid Tran-econ OE master paper 8½ x 11 or equal.

2. Numbering System

At this point in the production layout a filling system was inaugurated corresponding with the chapters of the course textbook and workbook. A file number was stamped on three items: a manila file folder, the master drawing and the color separation sketches (CSS). This became the basis of a master filing system for all the drawings and transparencies.

Average Time Consumed: ¼ minute per set.
Material: Justrite BN2-6 Numberer or equal.

3. Typing

At this stage, typing on the master drawing should include all the information found on each of the CSS sheets. It was not necessary to back up the master drawing with carbon paper.

Average Time Consumed: 12 minutes per master.

4. Printing

The original master drawing was used to make as many non-reproducible blue line intermediate prints as there were pages in the stapled color separation sketches. (CSS) It was determined toward the end of the reproduction process that one additional blue line print should have been run off at this time in case an error had occurred in inking or typing of the other prints or if a further change should warrant its use. Note: With the file number already stamped on the original master drawing, all the intermediate blue line prints contained the correct file number automatically.

Average Time Consumed: 6 minutes per transparency.
Material: Tecnifax Texray 214T or equal.

5. Inking

Each non-reproducible blue line print was inked according to the information contained on each of the CSS sheets. A distinct difference in the weight of lines (i.e., object lines, hidden lines, and sight lines) was emphasized more than usual.

Average Time Consumed: 11 minutes per blue line drawing.
Materials: Pelikan Drawing ink or equal. Pelikan Graphos ruling pen set or equal.

6. Typing

When typing the necessary information on each of the blue line drawings it is necessary to use at least a pica size type and back the drawings with either a black or orange colored carbon paper. This function allows for a good grade of opacity. Orange carbon has less tendency to smear.

Average Time Consumed: 3 minutes per drawing.
Materials: Ozalid Opaque Carbon Paper--Orange or equal.

7. Checking

This is best accomplished by use of a light table. After checking the blue line drawings against the master drawing and also the color separation sketches, they should be "placed in registry" on the light table. This will reveal any duplications of effort on more than one overlay and will also show lines passing through letters or words. This is a vital check on drawings in the subject matter area of descriptive geometry and will allow for a more professional presentation.

Average Time Consumed: 1 minute per drawing.

Upon completion of the preceding steps in the production process, each master file of drawings is complete. The manila file folder contains: (a) master drawing, (b) color separation sketches, (c) blue line prints, which in essence become known as the master blue drawings.

8. Printing

In this subject area of curriculum where sight lines are parallel to object lines and object lines become lines of intersection, registration of the overlays is of a vital concern in the development of the colored viewfoils. Considerable production time was lost at the beginning of this project because of inferior equipment. However, this problem has since been overcome and two types of equipment were utilized on the project. The Tecnislider device works well as an attachment on a high speed Ozamatic copying machine or equal. Another effective method of printing viewfoils was the Slidemaster system, which utilized the Protoprinter. While the latter method is somewhat slower, it is possible, with some experience, to print a large volume of viewfoils. There are several variables (age of viewfoils, age of photoflood bulb, and strength of ammonia) which, when coupled with inexperience, will increase the waste file. On this project wastage of viewfoils amounted to 19 percent, which was lower than originally anticipated. Spoilage of the nonreproducible blue line paper was somewhat lower--10 percent.

The method of development found to be most productive was to sort out 8 or 10 master blue line drawings from the manila folders which call for the same color view foil; run this number through with one setting of the timer; and then go on to another color and time setting. This allows for more efficient handling of the opened viewfoil packages. Ammonia fumes should not be allowed to contact open packages of film. They should be taped shut after the day's production run is finished or the package should be placed in a clear plastic bag. Caution should be stressed in obtaining the exact exposure of the viewfoils. This film is very sensitive, and one-quarter of a minute makes a difference in the printed results.

Average Time Consumed: 4 minutes per drawing.
Materials: Ozalid Viewfoil and Projecto Foil or equal, Technifax Diazochrome film or equal, Technifax Slidemaster System or equal.

9. Sorting

This is an automatic operation which hardly needs discussion, but it does take time on the production run. One fast way followed on this study was to lay out on a long table all the manila file folders that were involved in the day's run and then sort the viewfoil and master blue line drawings onto the proper file folder, making sure they coincided with the correct master pencil drawing and CSS inside the folder. This was difficult because of the close identification of some problems. Once all material is returned to the file folder, it is time-consuming to try to locate a misplaced viewfoil.

Average Time Consumed: ½ minute per drawing.

10. Assembling

Almost every project will entail somewhat different problems regarding this area; however, the author will go into some detail describing what was practiced on this project. The procedure followed here will not only enable a reader to augment his own ideas but will offer some new thoughts which only experience can supply.

In this project the first "visual" to be attached to the cardboard mount was called the given information and was always in black lines usually on a tinted base viewfoil. Because of the close registration which was required and the total number of problems involved, a Slidemaster System was utilized to advantage.

The cardboard mount was placed upside down on the pins with the visual (given information) next. Only two of the four sides were taped down in this position; one long side (pins) and one short side (staples) were omitted. This subassembly was removed and placed right side up on the pins again. If all subsequent overlays are to be hinged from one side, they should be aligned one at a time on the pins and metallized Mylar hinges attached. The three hinges should be positioned as far on the overlays as possible leaving only enough room for the staples and an equal amount both topside and underneath. If this is not adhered to accurately, after some usage, the overlays will "sag" out of registry. In this project most of the transparencies averaged five overlays and the visual (given information). Two staples were placed in each section of hinges; the two remaining pieces of tape were then applied on the back side of the mount. The ends of the staples are thus covered up, which permits easier filing. Finally, three small pieces of opaque tape were applied over the registration holes, and the file number was stamped on the mount. Any titles or lectures cues can be added if desired.

Average Time Consumed: 15 minutes per transparency.
Materials: Technifax Slidemaster System; Tape, Translucent, ½" matte-surface 3M-810; Techinges, 1¼" square Mylar pressure-sensitive; Stapler, Bostitch Model P6; Tape, Chart-Pak, ¼" #2512 Silver. Above materials or equal were used.

11. Filing

On this project the transparencies were first filed in a vertical position in sliding file drawers. After a short time, because of the many overlays per transparency, they all started sagging out of registry, which required the time-consuming process of rehinging many of the overlays. Hence, a horizontal storage cabinet with each slot holding approximately eight transparencies has been utilized with success. Finger marks, grease, pencil or dust may be removed from transparencies by rubbing or wiping with a soft lintless cloth.

Average Time Consumed: ¼ minute per transparency.

TOTAL TIME CONSUMED

Following is a tabulation by separate operations involved in the complete production of each of approximately 150 transparencies:

1. Drawings	225 Minutes
2. Numbering system	.0¼ "
3. Typing of masters	6 "
4. Printing of blue line prints	12 "
5. Inking	66 "
6. Typing of blue line prints	18 "
7. Checking	6 "
8. Printing of Viewfoils	24 "
9. Sorting	0½ "
10. Assembling	15 "
11. Filing	0¼ "
TOTAL	373 minutes

OR 6 hours and 12 minutes per transparency (Average = 5 overlays and 1 visual per transparency. Note: This time schedule is based on notes of each operation maintained during a production line operation. Probably eight hours would be closer to actual time necessary, if a single transparency problem were to be constructed after the individual had some experience in each operation.

COST ANALYSIS

When this research project was in the planning stage, it was impossible to ascertain a cost analysis that entailed one person's efforts in developing and printing his own transparencies. Therefore, a close analysis of material costs was maintained during the study and is broken down as follow:

Item	Cost Per Transparency
Mounts - 50 @ $10.00	$ .20
Diazochrome Film 8½ x 11, 25 sheet package @ $6.20	1.50
Tracing paper 8½ x 11, 500 sheets @ $2.50	.04
Texray paper 8½ x 11, 100 sheets @ $2.80	.16
Tape, ½" wide x 40" long translucent, 2592" @ $2.21	.03
Hinge, Mylar 1¼" square, 200 package @ $1.50	.11
Staples, Box 5,000 @ $2.70 (6 per transparency)	.01
	$ 2.05

This is an approximate (material cost figure only) for a transparency which contains 5 overlays and 1 visual.

Miscellaneous Supplies:

Erasers, pencils, black lead and colored leads, Ink @ .35 bottle, #4 Photoflood bulb, maximum life 10 hours @ $1.60, and ammonia, 1 gallon @ $1.25

Operational Costs:

Designed and constructed for a research project the transparencies described here have been utilized in teaching nine classes in descriptive geometry during the school years 1959-60 and 1960-61. No expense whatsoever has been involved in the maintenance of the transparencies themselves. However, below is a breakdown on the Transpaque Junior Projector bulb usage for the first year.

Started using projector September 14.

Fall Semester: Two classes - 1st bulb burnt out on December 17.

Spring Semester: Five classes - 2nd bulb burnt out on February 8, 3rd bulb burnt out on March 16, 4th bulb burnt out on April 27.

The last day the projector was used, May 17, the fifth bulb was still in use. From this record, one may arrive at a fair approximation of the number of hours a projector bulb might last. Seventy-five clock hours is an average operational figure for a 500 watt bulb. Care should be exercised in cooling the bulb immediately after use with the twin blowers of the projector for about four or five minutes. This allows the filament to cool before being moved, and the figure of 75 hours can be maintained.

CONCLUSIONS

In addition to the initial cost expenditure for transparencies a Transpaque Junior Overhead Projector was used which gave excellent service and proved to be one of the best projectors on the market. A projection screen was constructed out of tempered masonite mounted in an 8 ft. square frame which was designed to roll in the chalk tray. The screen leans out at the top to allow light rays from the projector to strike the screen at a 90-degree angle which eliminates any keystoning effect. These two items represent an initial outlay of approximately $450.00.

When one contemplates raising the standards of lecture demonstrations in curriculums which heretofore have required much blackboard communication, such as engineering descriptive geometry, the ultimate question to be considered is whether the costs described in this study can be compared favorably with the initial expenses of 150-175 square feet of slate, installation cost, continuing costs of chalk, blackboard erasers and daily custodial maintenance.

A Graphical Method for Working with Binary Numbers

By Charles J. Baer | The University of Kansas School of Engineering and Architecture

The nature of the circuitry of a digital computer requires an internal numerical system other than the decimal system, with which we are familiar. One of the most popular systems used is the binary, of which there are several variations. (See Table I.)

A person who works with a computer should know something about the internal numerics of the machine because he will occasionally find it necessary to read the lights on the console of the machine. These lights usually read in the binary, or whatever other internal code the computer uses. It is an axiom that a program never works the first time it is put into a computer. When the program stops, the lights (or on some machines, an oscilloscope) on the console show exactly where the program stopped and often give a clue as to what the error is.

One who is new at working with binary numbers may find it quite easy to make mistakes in addition, multiplication, and in reading these numbers. The alignment chart (Figure 1) will provide considerable assistance to such a person in checking his arithmetic. Although the numbers on the two side scales do not go very high, it should still be of value because the novice would probably want to work with numbers within this range. A similar alignment chart for the addition of such numbers would probably be of equal value.

The chart of Figure 16 was designed for the multiplication of conventional binary numbers from one to sixteen. For its top figure, the center line of the chart has the binary number 100000000, which is the equivalent of decimal number 256, the product of 16 times 16. Such a (binary) number may seem large and unwieldy but it can be handled very nicely by a computer designed for this type of binary system.

An example follows. Let us multiply 1010 (binary representation of decimal 10) by 1110 (decimal 14.) Using the alignment chart, we obtain the number 10001100 for the product. This number is the binary representation of decimal 140. The actual multiplication of these numbers would be as follows:

```
    1010
  x 1110
   10100
  1010
 1010
10001100
```

Note that in adding the fifth, sixth, and seventh columns from the right, we had to carry ones. This follows the rules of addition for binary numbers. Thus: 100 + 10 = 110 presents no carry-over problem but $100 + 110 = 1010$ requires a carry-over in the column that is third from the right.

The construction of this chart is quite simple. It is merely a chart of the form UV = W, having each exterior scale a little more than one logarithmic cycle long. The main problem was in deciding how to subdivide the center scale, particularly the upper part. In the final design, tick marks are positioned to give binary numbers whose intervals represent 10 decimal digits from 10 through 100 (1100100). Beyond 100, these marks are positioned to give numbers representing 120, 140, 170, 196, 225, and 256. There are also tick marks to represent 16 (10000) and 64 (not numbered). Although this arrangement is not 100 percent satisfactory, it is adequate for most checking purposes.

To assist the person who is interested in binary arithmetic, we have prepared Table II.

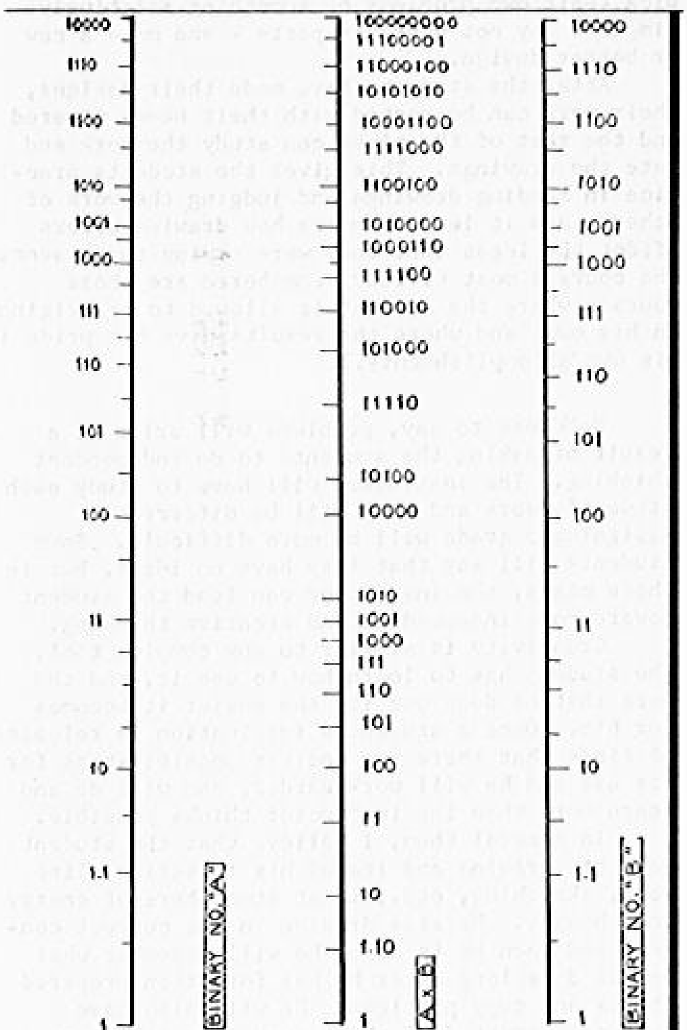

Figure 1

TABLE II

POWERS OF 2	BINARY NO.
$2^1 = 2$	10
$2^2 = 4$	100
$2^3 = 8$	1000
$2^4 = 16$	10000
$2^5 = 32$	100000
$2^6 = 64$	1000000
$2^7 = 128$	10000000
$2^8 = 256$	100000000
$2^9 = 512$	1000000000
$2^{10} = 1024$	10000000000

For example, let us determine the binary no. of 20. Twenty is 16 plus 4. The binary of four is 100 and the binary of 16 is 10000. Add these to get 10100. Also, the decimal number, 50, is 32 plus 16 plus 2. Thus, binary 50 is 100000 plus 10000 plus 10, or 110010. This can be found on the alignment chart.

A partial list of well-known computers and their numerical systems is: IBM 650, biquinary; IBM 1620, conventional binary; LGP 30, conventional binary and hexidecimal; Burroughs B5000, octal code.

TABLE I

DECIMAL	CONVENTIONAL BINARY	REFLECTED BINARY	BIQUINARY CODE	OCTAL CODE	HEXI-DECIMAL
0	0000	0000	0100001	0	0
1	0001	0001	0100010	1	1
2	0010	0011	0100100	2	2
3	0011	0010	0101000	3	3
4	0100	0110	0110000	4	4
5	0101	0111	1000001	5	5
6	0110	0101	1000010	6	6
7	0111	0100	1000100	7	7
8	1000	1100	1001000	10	8
9	1001	1101	1010000	11	9
10	1010	1111		12	F
11	1011	1110		13	G
12	1100	1010		14	J
13	1101	1011		15	K
14	1110	1001		16	Q
15	1111	1000		17	W
16	10000	11000		20	10

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Encouraging Creativity In Engineering Graphics

by Harold L. Dillenbeck
Instructor, Engineering Graphics, The Pennsylvania State University

An engineering graduate is not an engineer until he can create. The dictionary says that creative is synonomous with productive, and while this is partially true, creativity means more to an engineer. He must be able to bring forth new ideas, adapt old ideas to new products and practices, in short he must cultivate original thinking.

In The Report on Evaluation of Engineering Education* "The first objective, the technical goal of engineering education, is preparation for the performance of the functions of analysis and creative design.... The capacity to design involves more than mere technical competence. It involves a willingness to attack a situation never seen or studied before and for which data are often incomplete. This portion of many engineering curricula demands close scrutiny and continuous active change.... The emphasis should be on spatial visualization, experience in creative thinking, and the ability to convey ideas, especially by free-hand sketching, which is the normal mode of expression in the initial stages of creative work."
*(Journal Eng. Ed. Vol 46 Sept. 1955 P. 23-60)

Engineering Graphics courses are among the first courses that engineering students take, hence they are in an excellent position to start the student in his creative thinking. Frequently freshman drawing courses consist of many plates of pure copy work where it is hoped that the student learns by copying the work of others. With the use of creative design problems, however, the student can learn the usual techniques of lettering, dimensioning, sketching, visualization, sectioning, etc., in their true context. He can see why certain conventions are used, how they simplify the work he is doing. He can see that drawing is a tool of engineering, that its use is necessary in making a design, and that it will be used in all of the steps of creating an object or design. He can see that drawings are a means of communication and if the drawing is poor, it is as bad as a poor telephone connection or a loose tube in a radio or television for it does not and cannot tell the whole idea, and, as a result, the idea is lost.

With creative design, we have an opportunity to show drawing in its proper context in the field of engineering. Drawing is a tool, a very useful and necessary tool, and in this type of situation, the instructor can show how it is used and, at the same time, make the whole course more meaningful. The time spent on creative design should approach the real life work of an engineer. The more that can be done to make this realistic, the better the students can carry over their learning to their later life.

During the time spent on creative design, the student can be introduced to engineering ethics. He can be shown that he is to create, not copy someone else's work - shown that his work is his own and must stand or fall on his own knowledge and ability. The fact that most work of engineers is of a professional nature and is directly concerned with public safety can be shown with examples. Here, too, the student can see that the engineer must work for his company, must feel that the men, materials, etc., are his to use in the best interests of his employer, must deplore waste in all respects, such as time, effort, and money. In short, he can begin to understand the meaning of ethics and professionalism.

Creativity can be introduced from the beginning of the student's first drawing class. He can be asked to make a geometrical design in his first practice with instruments rather than copying one from the text. He can be asked to draw a door stop, a wrench, or some simple object rather than copy a multilated block from his book. As the course progresses, the instructor can ask the student to design a screw jack or some other assembled object. The most interesting results come from asking the students to "design something", pick their own problems of something relatively simple - say not over six parts - and make a new or better design.

After the students have made their designs, their work can be posted with their names covered and the rest of the class can study the work and rate the drawings. This gives the students practice in reading drawings and judging the work of others, and it lets them see how drawing errors affect the ideas that they were trying to present. The courses most vividly remembered are those courses where the student is allowed to be original, on his own, and where the results give him pride in his own accomplishments.

Needless to say, problems will arise as a result of asking the students to do independent thinking. The instructor will have to study each student's work and each will be different. Assigning a grade will be more difficult. Some students will say that they have no ideas, but in these cases, the instructor can lead the student toward more independent and creative thinking.

Creativity is similar to any complex tool. The student has to learn how to use it, and the more that he does use it, the easier it becomes for him. Once a student's imagination is released, he finds that there are endless possibilities for its use and he will work harder, and will do and learn more than the instructor thinks possible.

In general then, I believe that the student does his drawing and learns his lettering, line work, sketching, etc., in an atmosphere of energy and thought. He sees drawing in the correct context and when he is done, he will remember what he has done long after he has forgotten prepared sheets and copy problems. He will also have learned a great deal about such intangibles as ethics, professionalism, and independent work. As a preparation for his future work, both in college and later in the industrial world, the early release of creative thought must be fostered.

SOLUTION OF Circles Tangent to Three Circles PROBLEM BY HYPERBOLIC LOCI

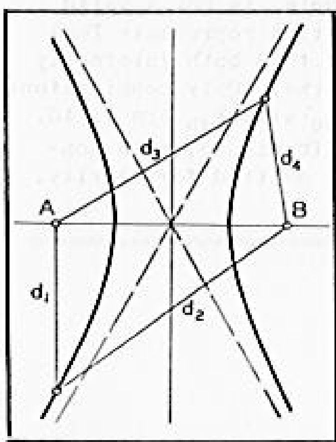
By Michael P. Guerard

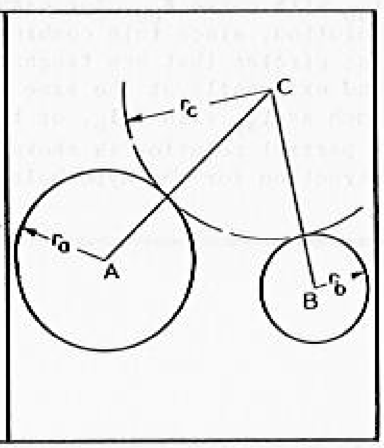
Many of the "classical" and purely academic problems of geometry can be solved by the principles of intersecting loci. Solutions for which the loci in question are straight lines or circular arcs are most widely accepted, since they can be accomplished through the use of Euclidean geometry, i.e., with straight-edge and compasses.

Presented herein is a possible, though admittedly tedious, solution to the old problem of finding the centers of all circles tangent to three given circles. The solution proposed uses not straight line or circular arc loci, but hyperbolic loci, which, however, may be constructed with straight-edge and compasses. It turns out that the centers of all circles tangent to two given circles lie on a pair of hyperbolas. The two hyperbolas arise from the two possible cases: one, that the required circle either contains or does not contain both given circles (Case I), and the other, that the required circle contains one of the given circles, and not the other (Case II). The proof that the loci are hyperbolas begins with a geometric definition of a hyperbola:

> A hyperbola is the locus of a point moving so that the absolute value of the difference between the undirected distances from the moving point to two fixed points remains a constant.

In Fig. 1, $|d_1 - d_2| = |d_3 - d_4|$ = constant.





A and B are the foci of the hyperbola. (There is a conjugate hyperbola associated with the one shown, but is of no consequence here.) The application to the problem at hand is as follows:

Consider Case I, which in turn may be broken down into two parts, Case Ia (required tangent circle contains neither given circle), and Case Ib (required circle contains both given circles). For Case Ia, refer to Fig. 2. Shown are the two given circles, with centers at A and B, and radii r_a and r_b, respectively. Point C is the center of a typical tangent circle with radius r_c. Drawing AC and BC, we see that

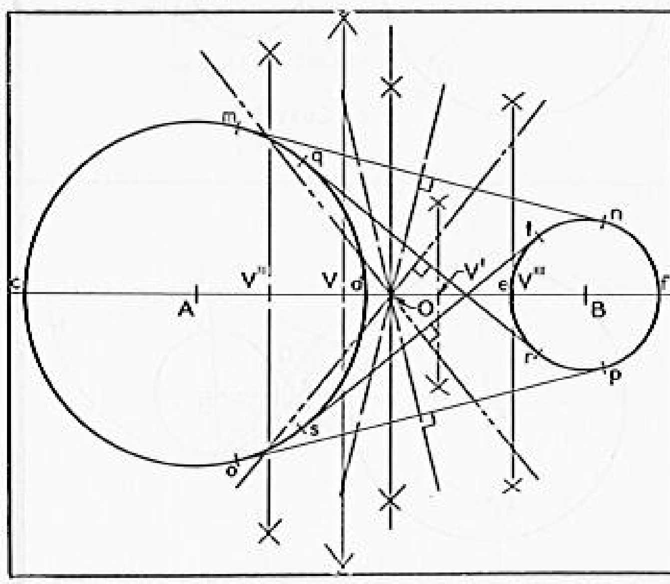
$$|AC - BC| = |(r_a + r_c) - (r_b + r_c)| = |r_a - r_b| = K_1$$

AC and BC are the undirected distances from point C (a movable point) to points A and B (fixed points). Thus point C satisfies the locus in the definition of a hyperbola. A completely analogous situation exists for Case Ib. The reader may easily verify that for this case, the constant is $|r_b - r_a| = |r_a - r_b| = K_1$.

The analogy continues for Case II, which also may be divided into two parts, IIa and IIb, depending upon which of the two given circles is contained in the required tangent circle. It can be shown that for this case, the constants are $|r_a + r_b| = K_2$ and $|- r_a - r_b| = |r_a \quad r_b| = K_2$. The constants K_1 and K_2 show that there are two hyperbolic loci for all possible circles tangent to two given circles, and the proof is complete.

The method of solution to the main problem, then, involves finding the hyperbolas for each of two different pairs of the three given circles. The intersections of these loci (discriminately chosen, as will be shown later) give the centers of all circles tangent to the three given circles. It can be deduced that in general, there are eight such circles possible: one containing all three given circles, one excluding all three, 3 containing one and excluding two, and 3 containing two and excluding one, making eight in all.

It remains to find a method for constructing the hyperbolas, or more specifically, to find some parameters such as axes, asymptotes, and vertices. The steps in the construction are as follows, illustrated in Fig. 3:



1. Bisect AB at point O. AB and its bisector are axes of both hyperbolas, and O is the origin.

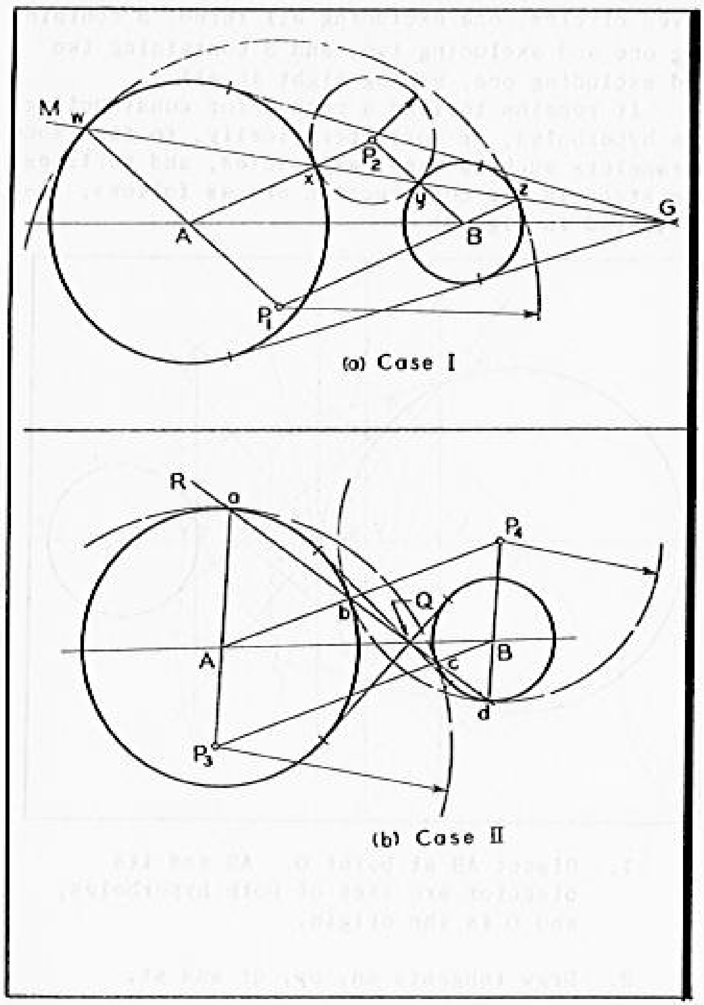
2. Draw tangents mn, op, qr and st.

3. Through O, draw perpendiculars to the four tangents. These perpendiculars are the asymptotes of the hyperbolas.

4. Bisect cf at V and de at V'. V and V' are the vertices of the Case I hyperbola.

5. Bisect ce at V'' and df at V'''. V'' and V''' are the vertices of the Case II hyperbola.

Having found the foci, axes, asymptotes and vertices of the hyperbolas, any convenient method may be used for constructing them; however, the method illustrated in Fig. 4 is reasonably rapid and accurate provided the circles are sufficiently different in size. Case I and Case II are shown separately for clarity. For Case I (Fig. 4(a)), locate point G by drawing the outside tangents to both circles as shown. Draw any secant, GM, intersecting both circles in points w, x, y and z. Radii Ax and By extended intersect at P_2, and Aw and Bz extended intersect at P_1. Note that AP_2BP_1 is a parallelogram, and that P_1 and P_2 are symmetrical to the origin. More points may be found by drawing other secant lines from G, and proceeding as before.



(a) Case I

(b) Case II

For Case II (Fig. 4(b)), locate point Q by drawing both inside tangents as shown. Draw any secant, RQ, intersecting both circles in points a, b, c and d. Radii Aa and Bc extended intersect at P_3, and Ab and Bd extended intersect at P_4. The same symmetry is evident as for Case I, and more points may be found similarly.*

It is suggested that some form of notation be used to label each curve found, so that discriminate choice of curve intersections may be made; not all such intersections are valid solutions. For example, suppose the three given circles are labeled A, B and C. Each locus satisfies the requirements for two circles, say A and B, with four possibilities; the tangent circle may;

1. Contain both A and B (label I_{ab}), or

2. Contain neither A nor B (label E_{ab}), or

3. Contain A but not B (label I_aE_b), or

4. Contain B but not A (label I_bE_a).

These four possibilities represent each branch of the two hyperbolas, with "I" meaning "tangent <u>internally</u>" and "E" meaning "tangent <u>externally</u>". With this notation, if the second pair of circles chosen is say, B and C, the intersection of curve I_{ab} with curve E_{bc}, for example, is not a valid solution, since this combination represents loci for circles that are tangent to B both internally and externally at the same time. Only combinations such as I_{ab} with E_cI_b, or E_{bc} with E_{ab} are valid. A partial solution is shown in Fig. 5, with construction for the hyperbolas omitted for clarity.

◄ *Figure 4*   *Figure 5* ►

*Space does not allow including the proof of the validity of the foregoing constructions, but the author will be happy to provide them on request. Write c/o Department of Graphics and Engineering Drawing, Princeton University, Princeton, New Jersey.

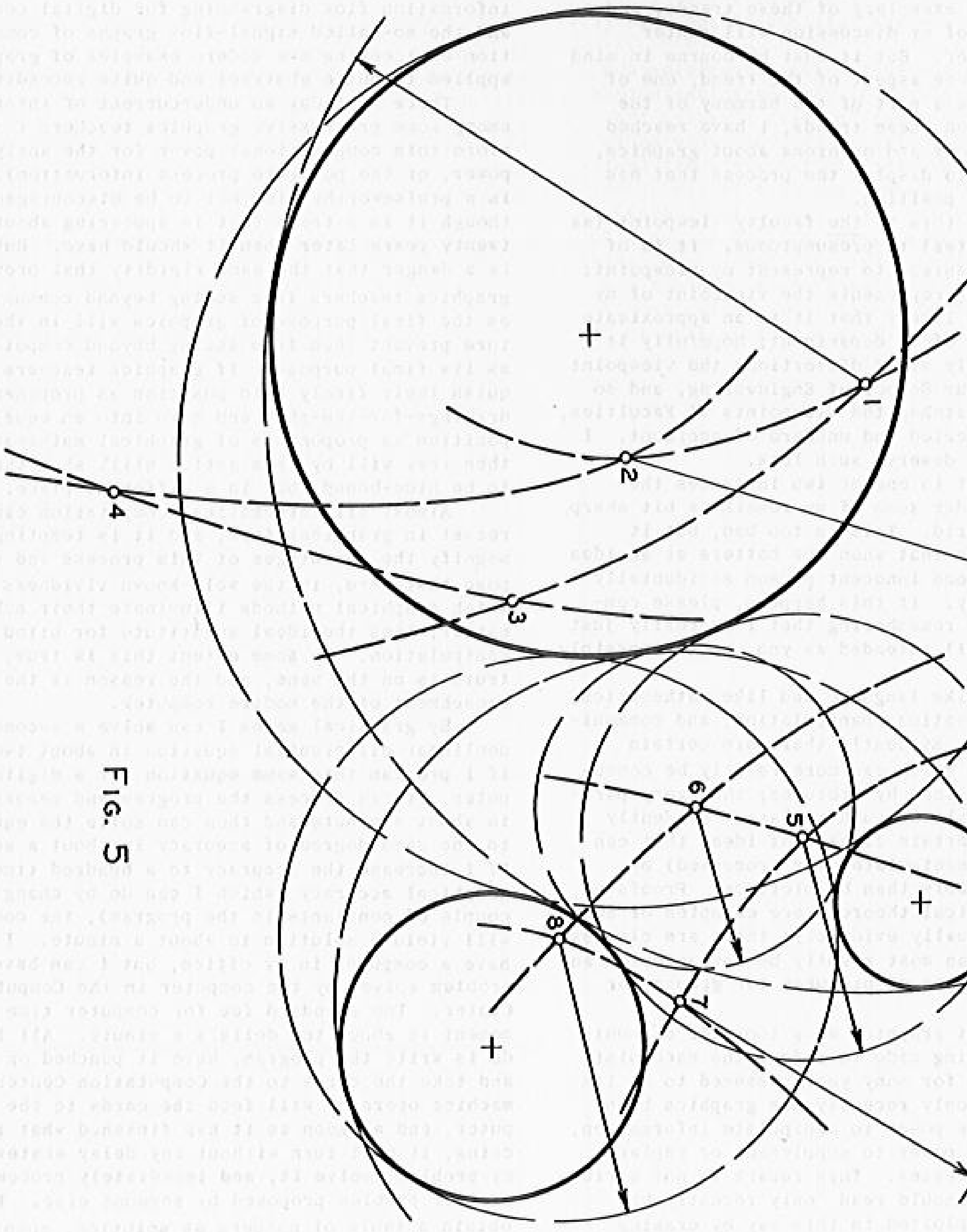


FIG. 5

By Steven Anson Coons, Associate Professor of Mechanical Engineering—Massachusetts Institute of Technology

There are certain trends and directions in engineering, both in the profession and in education; they are so strongly marked that it is impossible to ignore them. I have singled out one strong vector as exemplary of these trends, and a very large part of my discussion will center around this vector. But it must be bourne in mind that it is only one aspect of the trend, one of the notes that is a part of the harmony of the whole. Based upon these trends, I have reached certain conclusions and opinions about graphics, and I shall try to display the process that has brought me to my position.

To say that this is the faculty viewpoint (as the title indicates) is presumptuous. It is of course only guaranteed to represent my viewpoint; it also (happily) represents the viewpoint of my division; it is likely that it is an approximate of the viewpoint of my department; hopefully it reflects with only minor distortions the viewpoint of the Dean of our School of Engineering, and so on. But if it matches the Viewpoints of Faculties, this is an unexpected and unheard of accident. I scarcely think I deserve such luck.

I think that in one or two instances the reader may consider some of my remarks a bit sharp, even possibly acrid. This is too bad, but it sometimes happens that when one batters at an idea to demolish it some innocent person accidentally stands in the way. If this happens, please comfort yourself by remembering that I am really just as kindly and well intended as you are, or possibly even more so.

Graphics, like language and like mathematics, is a tool for creation, manipulation, and communication of ideas. Evidently there are certain classes of ideas which can more readily be communicated by words than by pictures; this very paragraph is an example of such a class. Evidently too, there are certain classes of ideas that can more readily be manipulated (or processed) by mathematical symbols than by pictures. Proofs of general mathematical theorems are examples of such a class. But equally evidently, there are classes of ideas which can most readily be communicated and manipulated by means of pictures (or graphs, or drawings).

The power of graphics as a tool for communication (the drawing made to inform the machinist in the shop) was for many years assumed to be its only power, and only recently has graphics been exploited for its power to manipulate information, that is, for its power to supplement or replace mathematical processes. This remark is not strictly accurate; it should read "only recently has graphics been exploited in this way by drawing teachers" because the sad fact is that graphical methods, where appropriate, have been freely used in other fields than graphics. For example, Mohr's circle in stress and strain analysis, vector representation of complex numbers in electrical engineering and in control system engineering, flow mapping in fluid dynamics, graphical vector analysis of kinematic systems, are a few instances of classical applications of graphics. More recently, information flow diagramming for digital computers, and the so-called signal-flow graphs of communication engineering are modern examples of graphics applied to quite abstract and quite recondite ideas.

There is today an undercurrent of interest among some progressive graphics teachers to explore this computational power (or the analytical power, or the power to process information). This is a praiseworthy aim, not to be discouraged, even though it is a trend that is appearing about twenty years later than it should have. But there is a danger that the same rigidity that prevents graphics teachers from seeing beyond communication as the final purpose of graphics will in the future prevent them from seeing beyond computation as its final purpose. If graphics teachers relinquish their firmly held position as proponents of drawings-for-the-shop and move into an equally firm position as proponents of graphical mathematics, then they will by this action still show themselves to be hide-bound, but in a different place.

Almost all mathematical computation can be recast in graphical form, and it is tempting to magnify the advantages of this process and to suppose that here, in the well-known vividness with which graphical methods illuminate their subject matter, lies the ideal substitute for blind symbol manipulation. To some extent this is true, but the truth is on the wane, and the reason is the encroachment of the modern computer.

By graphical means I can solve a second order nonlinear differential equation in about two hours. If I program this same equation for a digital computer, it can process the program and memorize it in about a minute and then can solve the equation to the same degree of accuracy in about a second. If I increase the accuracy to a hundred times the graphical accuracy (which I can do by changing a couple of constants in the program), the computer will yield a solution in about a minute. I do not have a computer in my office, but I can have the problem solved by the computer in the Computation Center. The standard fee for computer time at the moment is about ten dollars a minute. All I need do is write the program, have it punched on cards, and take the cards to the Computation Center. The machine operator will feed the cards to the computer, and as soon as it has finished what it was doing, it will turn without any delay whatever to my problem, solve it, and immediately proceed to another problem proposed by someone else. I will obtain a table of numbers as solution, complete with headings telling what the variables are, or I can if I wish obtain a graphical output, or both.

If I make a mistake in writing the program, the computer will diagnose the trouble and write me a note telling me what I did wrong. In this case the computer will not attempt to solve the problem until I have furnished it with a properly corrected program.

Today programming a digital computer is a somewhat elaborate process, requiring a knowledge of a special language which lies midway between ordinary English and an unintelligible foreign computer language, a knowledge of certain syntactical rules (or more properly, a knowledge of computer logic), and absolute freedom from error in spelling and punctuation. Since the computer is absolutely intolerant of the human frailties that plague us all, it is unusual to have the first draft of a program run without criticism by the computer. But once the program is acceptable, it is a permanent part of the computer mechanism, a part that I can remove and take home with me. If I write it well, it will be a mechanism that will solve any differential equation, and give me results in a minute or two.

Tomorrow the programming will be nearly automatic. Already great strides have been taken in this direction. I have seen the formula for a general second degree curve equation typed out on the input typewriter of a computer in conventional algebra, and I have watched the curve being drawn on the output oscilloscope the instant the typing was finished. Tomorrow I will have direct access to the computer through a console in my office. I will be able to obtain solutions to any mathematical problem that I can formulate, using my own symbols, and talked about in my own language. What is more, I will be able to draw pictures of three-dimensional objects, and I will be able to participate or collaborate with the computer in solving all problems of descriptive geometry concerning the shape of the object. When the computer and I have, together, decided upon a suitable shape for my design, I will be able to ask the computer to test the object for strength subject to the applied loads. If all is acceptable, I can then require the computer to draw me a dimensioned three-view drawing of the piece, with adherence to all the drafting conventions, suitable for information to the machine shop, or I can require the computer to prepare a punched tape to control an automatic milling machine to cut out the part from a block of aluminum or steel.

If I elect to have the computer prepare a dimensioned detail drawing of a part, it will take about a second for the drawing to be produced. This will be the equivalent of a day's work by the average detailer, because the machine can draw faster, never makes mistakes, never goes out for a coffee break, and never day dreams about how to get even with the boss.

How soon will this opium dream congeal into an accomplished fact? The truth is that most of the pieces of the system exist right now; they only need to be shaped to fit one another and screwed together. I have with my own hand drawn two-dimensional objects with a light pen on an oscilloscope screen, and the computer has "understood" the drawing and has demonstrated its understanding by drawing it back to me, but of course much more rapidly. I have seen a three-view orthographic drawing of an object transformed into a perspective pictorial, and then into an axonometric pictorial. I have seen the viewpoint of the pictorial change as I watched, so that the object was in effect rotated, on command, in space. We already know how to perform all the operations of descriptive geometry on the computer. We already know how to describe parts whose surfaces are doubly curved, and doubly curved in the most general way -- not simply spherical nor toroidal nor ellipsoidal, but sculptured. These last mentioned capabilities are not yet implemented, but it will be only a matter of weeks or months until this will be an accomplished part of the system. We already know how to perform stress analysis calculations on general shapes, all quite automatically. This is being implemented.

You are probably thinking that computers are too expensive for any but the most wealthy organizations to own and operate. Assume that a computer to do the things I outlined were to cost a million dollars. We can assume that after this capital outlay it costs about 20% of this figure per year to operate, update, and maintain the computer. This is a conservative figure for what I want to indicate and is possibly higher than need be. This represents $200,000 per year for a facility to replace a crew of detail draftsmen, together with the drafting room to house them, supervisors to administer them, drafting tables and equipment and supplies for them to use (and misuse) and other parasitic expenses. If we assume the cost to the company for all these items including salary to be $10,000 per year per detail draftsman (again a conservative figure) then we break even if the computer can replace twenty draftsmen, and we begin to make money if we replace more than twenty. But this is not a large organization; it is only medium sized. Moreover, if the computer can also replace technicians of higher ability, like stress analysts, we begin to reap even richer benefits. This argument seems to be applicable to medium size (not giant) engineering offices. For the very small company, outright ownership of a large computer is not feasible at present (although small computers are not too expensive). But it seems likely that computation centers will spring up some day to serve such small companies on a job shop basis, so that eventually even the small company will be able to avail itself of such facilities. When this happens, it will be cheaper to have detail analyses and drawings done by machine than by man. The routine operations will be done, as they should be done, by mechanical slaves, and the human will be free to perform his proper task of creation of ideas.

This is obviously crazy talk, like suggesting that a man can fly to the moon!

That the computer will some day do the things I suggest in this paper is a certainty. It is as inevitable as was the industrial revolution, the automobile, and the airplane. That it will require major economic readjustments is not inevitable, but is unfortunately very likely, because as history shows there are too many people who prefer to believe until the end that "the automobile is only an expensive toy of the rich," that "if the good Lord had intended man to fly He would have given him wings," and that "the machine can never replace the craftsman." When subsequent events proved these arguments false, it was too late to prepare for the economic upheaval that could have been avoided. Of course, today we see that the eventual outcome of these revolutionary changes has been economically good, even though in transition it was a painful process. But in retrospect we see that an acceptance of these ideas rather than a refusal to face them might very possibly have led to intelligent action to assimilate the new system.

It is becoming clear that we must re-evaluate what is the computable part of human intellectual activity and what is the part that must continue to be performed by the human mind. The first observation that emerges from such a re-evaluation is the obvious remark that the human mind must understand the processes of the computer, even though the performance of these processes is mechanical. This remark could have been anticipated in a trivial case; a desk calculator can perform arithmetical operations, but of course the operator must understand arithmetic. Now let us turn to a more sophisticated example: computers are being used to design the arrangement of parts, wiring, and to simplify the switching circuits of newer computers. In other words, computers are designing themselves. The superficial conclusion could be drawn that if computers are able to design systems as elaborate as other computers, there is no need for human brains at all any more, and our children can quit school and devote all their time to games. But of course this is a completely frivolous conclusion; the truth is that this growing ability of the machine to carry out intellectual processes of higher and higher orders does not crowd the human intellect out of business, but instead frees it to undertake higher and higher orders of creative activity, to invent and manipulate grander and larger ideas, and to leave the fine structure of these ideas to the computer for the drudge work of their manipulation.

The role of graphics in the emerging world of the computer will be no less important than it is today. We will still need to teach graphical communication, machine drawing, and drafting conventions; we will still need to teach graphical computation, graphical calculus, empirical curves, and the like. But more than ever we will need to emphasize the role of graphics as a tool for aiding creative thought processes. The emphasis on skill and precision will have to be relaxed in favor of a stronger emphasis on understanding and insight. Even in the case of graphical computation, the freehand sketch can carry a great deal of the burden of graphical elucidation of principle, and it appears that in the future only elucidation of principle will be needed by man; the actual application of principle is a mechanical operation that should be done and will be done by machine. Thus the content of a good graphics course of the future will not differ very markedly from today's good graphics courses, but the emphasis and point of view will have changed. The elements of drill and detail will have disappeared to make room for the elements of exploration, invention, and understanding. We will strive to equip the student with the same facility in graphics that he enjoys in mathematics. It does not require that a student undergo laborious drill in arithmetical computation; facility in verbal expression does not require that a student master the skills of an expert penman, nor that he be able to compete with an expert typist, nor, in a closer analogy, that he copy word for word passages from the major poets. Similarly, facility in graphics of a kind that makes graphics of equal intellectual weight with mathematics and language must, for its development, require much more than rote drill, copywork, repetition of dreary lettering exercises, and fussy adherence to unexplained drafting conventions. These are the antiquated techniques of apprenticeship training, suitable for the development of artisans and technicians; but apprenticeship training is not education; artisans are not artists; and technicians are not engineers.

There is also the aspect of style. I cannot precisely define it, but it is the recognizable attribute of good literature; it is what the mathematician calls "elegance" when describing a particularly artistic and gracile proof; and it is what we have all seen in drawings prepared by a few of our students who happen to have a certain flair. In whatever intellectual form style manifests itself, whether literary, mathematical, or graphical, it is the finest attribute of the artifacts of the intellect, and it is the clearest manifestation of the intellectual quality of its creator.

Style bears the same relationship to technique that artistry bears to artisianship. Style is the product of a creative activity; technique is merely the product of repetitive training. Although technique may contribute to the easier achievement of style, technique by itself without disciplined, critical, creative effort cannot achieve style. Specifically, one way to help to achieve it is to train ourselves and our students to recognize it in the work of others, to analyze the means by which it has been obtained, and to put forth a constant effort to produce it in our own work.

There has been considerable discussion in this paper about the predictable role of the computer in our future engineering life. There is a possibility that the reader may infer from this that the role of the computer is essential to the conclusions

I am about to draw. This is not so. I have talked at length about the computer, and I am afraid that I may have presented it to appear out of proportion, larger than life. Instead, the reader should remember that the trends that accompany computer development are the same trends that were evident even before computers existed, but now the trends have been accelerated. When I was a practicing designer, fifteen years ago, these trends were evident. It was policy even then for the design engineer to create, or invent, if you will, the basic design, and to turn this design over to a crew of draftsmen working under his supervision to introduce the fine structure and prepare the detail drawings for the shop. The designer habitually used freehand sketches for his design, and he often also used freehand sketches to instruct his draftsmen in the process of performing a graphical construction of some mathematical analysis. This is very much like programming a computer.

The considerations outlined in this paper lead me to believe that the two functions of graphics, communication and analysis, are not the full measure of its power, but that its function as an aid to creative thought is even more important. I would like to generate in my students a frame of mind that would make them instinctively reach for a sketching pencil when they were confronted with a problem. I would like them to have appropriate faith in the dependability and applicability of a graphical sketch, the same faith that they have in arithmetic and mathematics. I cannot with honesty recommend to them that they solve, for example, quadratic equations for both real and complex roots by graphical means (even though this is quite possible), because it is really easier to solve such equations by algebra and arithmetic. But there are problems that are easier to solve graphically than by algebra and arithmetic, and if I am scrupulously honest with them about the appropriateness of graphics, then I will build their faith upon a firm foundation. In the case of the creative act, the formation of an initial concept, I can with complete honesty (since I believe it myself) assure them that graphics has in many applications the greatest or perhaps the only power; that words and mathematics are in these cases useless.

I would like them to use graphics as a tool to aid the understanding. As I have suggested before, many abstractions can be cast in graphical form, and in this form they are best illuminated for the scrutiny of the mind.

And last, I would like my students to form a sensitivity for that elusive thing called style. Once recognized and sought after in graphics, it will be a kind of induction appearing other modes of thought and expression, and will ultimately emerge in all their works as a priceless element of quality.

Progress Report 9 ENGINEERING GRAPHICS COURSE CONTENT STUDY

Sponsored by the National Science Foundation

Paul M. Reinhard, Project Director

This report has been prepared to inform the Engineering Graphics Division membership of recent and current activities of the Graphics Development Project. It will: 1) summarize the results of the Planning Seminar conducted at the University of Detroit on the 26th and 27th of October, 2) review discussions of the Core Committee Meeting at the University of Wisconsin on January 17th, 3) elaborate on plans for area workshops scheduled during the month of April, and 4) announce a tentative agenda for the Joint Core-Steering Committee Development Seminar at the University of Princeton on May 7th and 8th.

PLANNING SEMINAR:

To officially start the Engineering Graphics Course Content study, a two day planning seminar was held at the University of Detroit in October. The first day of the seminar was devoted to a Core Committee discussion of the general and specific objectives of the project, a definition of the duties of participants, budget allotments, probable areas for graphics study, and designation of responsibility for subject matter development in the selected areas. All eight committee members were in attendance.

A second planning conference was held the following day with eight Core and eight Steering Committee members present. Dr. Richard E. Paulson, Program Director of the Course Content Improvement Section, represented the National Science Foundation. The threefold purpose of the morning sessions was:

1) To orient the thinking of both committees relative to the aims and scope of the study.
2) To discuss and tentatively select several general areas of subject matter for exploration and development.
3) To determine methods and procedure for implementing the initial phase of the project.

In the afternoon, objective discussion by Steering Committee members disclosed the need to:

1) Define clearly the subject matter of graphics and its role in engineering education
2) Identify the objectives of engineering education that can be served by the inclusion of the discipline of graphics in the curriculum.

3) Determine the most effective manner by which the student can be instructed.
4) Provide for adequate training and upgrading of faculty members responsible for a scientific oriented graphics program.
5) Establish leadership in the comparatively new field of automatic processing of graphical information.
6) Explore the utilization of graphics as a tool in the solution of non linear systems.
7) Consider grades of curricula with modifications for particular engineering disciplines.
8) Differentiate between the scientist and the engineer and examine the duties of the engineer at various levels of his professional development.
9) Enrich engineering graphics courses at freshman and sophomore level.
10) Emphasize the value of a knowledge of all aspects of graphics to the engineer.

By joint committee action, it was decided to concentrate project efforts in four broad areas of graphics development. Core Committee responsibility was also determined to provide leadership in each of the selected areas.

1) Automatic processing of graphical information inclusing analog simulation. (Dean Carson P. Buck)
2) Creative Engineering Design. (Professor Matthew McNeary)
3) Research and Industrial Applications. (Professor Alexander S. Levens)
4) Graphical Analysis and Computations. (Lt. Col. Robert H. Hammond and Professor Lewis G. Palmer)

CORE MEETING AT MADISON, WISCONSIN

The meeting of the Graphics Core Committee at the University of Wisconsin on January 17th was devoted to:

1) A review of the six months progress report
2) Presentation of representative problems for each of the four major areas of the study
3) A discussion of the graphical output of digital computers
4) The role of creative design in modern engineering education
5) Implementation of the development aspects of the project.

Six members of the Core Committee together with Professors Steven A. Coons of Massachusetts Institute of Technology, Edward M. Griswold of The Cooper Union, and Forrest M. Woodworth of the University of Detroit attended.

Professor Woodworth presented several problems which correlated graphics with computer programming, research, design, and the computational aspects of engineering education. Professor Coons explained the increasingly important role of the computer in engineering design in these words; "I can require the computer to draw a dimensioned three-view drawing of the piece, with adherence to all drafting conventions, suitable for information to the machine shop, or I can require the same computer to prepare a punched tape to control an automatic milling machine to cut out the part from a block of aluminum or steel." Probably the most pertinent observation made by Professor Coons was that "Graphics'strongest contribution is as a tool for aiding creative thought processes".

To accelerate the development phase of the project, it was decided to schedule five area workshops prior to the Seminar at the University of Princeton in May. Each workshop would be attended by six or eight engineering educators representing disciplinary and degree granting departments of the engineering curricula. The purpose of these sessions would be to:

1) Define the specific areas of development and indicate what each includes.
2) Clearly show how all facets of graphics may serve as an integrating medium for other engineering courses.
3) Prepare subject matter and typical problems which will illustrate the general content of the several units of instruction.

The Core Leader, who is responsible for directing the workshop, will present to the Steering Committee at Princeton a detailed resume of work in progress for the committee's objective evaluation. With the presentation of tangible useable material, the development phase of the project will be under way.

DEVELOPMENT WORKSHOPS

During the month of April, engineering educators and industrialists have been invited to participate in the following workshops:

CREATIVE ENGINEERING DESIGN at Massachusetts Institute of Technology on April 27th

Professor Matthew McNeary, Director
University of Maine

Professor Joseph E. Shigley
University of Michigan

Professor Kenneth E. Lofgren
The Cooper Union

Dr. Robert W. Mann
Massachusetts Institute of Technology

Professor B. Leighton Wellman
Worcester Polytechnic Institute

Professor Percy H. Hill
Tufts University

ANALOG COMPUTER SIMULATION at Michigan State University on April 13 & 14

Professor James R. Burnett, Director
Michigan State University

Professor James E. Stice
Illinois Institute of Technology

Dr. Gerald M. Smith
University of Nebraska

Dr. Robert M. Howe
University of Michigan

Dr. James O. Osburn
University of Iowa

Professor Earl C. Zulauf
University of Detroit

GRAPHICAL ANALYSIS at the University of Minnesota on April 26 & 27

Professor Lewis G. Palmer, Director
University of Minnesota

Professor Ernest F. Manner
University of Wisconsin

Professor Frank Raley
North Dakota State University

Professor M. W. Almfeldt
Iowa State University

Professor Frank M. Harchovsky
Illinois Institute of Technology

Professor Richard D. Springer
University of Minnesota

GRAPHICAL OUTPUT OF DIGITAL COMPUTERS at Massachusetts Institute of Technology on April 2 & 3

Dean Carson P. Buck, Director
Syracuse University

Professor Steven A. Coons
Massachusetts Institute of Technology

Professor Myron G. Mochel
Clarkson College of Technology

Mr. Samuel Matsa
IBM Corporation

Professor James S. Rising
Iowa State University

Professor Forrest M. Woodworth
University of Detroit

GRAPHICAL COMPUTATIONS at the United States Military Academy on April 18 & 19

Lt. Col. Robert H. Hammond, Director
United States Military Academy

Professor Steve M. Slaby
University of Princeton

Professor Jacob H. Sarver
University of Cincinnati

Professor Ernest R. Weidhaas
Pennsylvania State University

Professor Mary F. Blade
The Cooper Union

Professor Klaus E. Kroner
University of Massachusetts

PRINCETON SEMINAR: May 7th and 8th

On May 7th the Core Committee met to: 1) answer questions raised by the Steering Committee at the October Seminar, 2) review reports of workshop accomplishments, and 3) prepare a logical presentation of development work in progress for the advisory meeting. Plans for continuation of project work during the summer months were formulated. A report summarizing the first years progress will be prepared for distribution by the Project Director prior to the next joint meeting of the committees. An invitation has been extended by Professor Edward M. Griswold, Chairman of the Engineering Graphics Division, to hold a fall seminar at The Cooper Union.

The second session was a joint meeting of Core and Steering Committees which heard a review of proposed graphics course subject matter, a presentation of typical problems, and a general informational description of the key role of graphics in modern engineering curricula. The advisory group has been asked to objectively evaluate the presented material and recommend where to expand and concentrate further developmental research studies. Guided by their direction and observations, it is anticipated that future workshops will reflect the thinking of this influential committee.

SOME APPLICATIONS OF *Descriptive Geometry To Solar Astronomy*

By C. E. Rowe, Professor Emeritus of Drawing, The University of Texas

This article presents some unusual and interesting applications of descriptive geometry. A high school student, Robert Owendoff, selected for his Virginia Academy of Science Project a study of solar shadows. He suggested that many of his observations could be checked by descriptive geometry. One of these was the determination of true north by using the method of equal shadows of a vertical rod on a horizontal plane.

This article deals with the following:

1. To find graphically the tip-shadow curve at any latitude for any day of the year, and to find true north.

2. To construct a sundial, and to check the tip-shadow curve.

3. To find graphically the time and direction of sunrise and sunset, and the length of day.

The following solutions have been developed:

1. Referring to the drawing, a vertical rod VR is shown at 40^{o} north latitude in the right side view of a miniature earth. It is desirable to think of the sun as moving around V as a stationary point. The sun's rays generate a declination cone with its axis parallel to the earth's axis. The declination used is 20^{o}N as found in a solar ephemeris for a certain summer day (and is assumed to be constant for the day). A ray from the sun passes V and follows the second nappe of the cone, which is the same as the south declination cone, and casts its shadow on the horizontal ground plane G for latitude 40^{o}. The front auxiliary view is a normal view of this ground plane, and the rod shadows and tip-shadows are shown on it. The curve is a hyperbola.

If the declination of the sun is 20^{o}S, the second nappe of this south declination cone is the same as the north declination cone and the horizontal plane G intersects its elements at the tip-shadows of the rod. In the auxiliary view this winter tip-shadow curve is a hyperbola. It should be noted that the base circle used for each cone is that for its second nappe, and it is divided into 24 parts for the hours of the day.

After making the proper set-up of the declination cone, the solution for the tip-shadow curve is that for a conic, which is usually a hyperbola but is an ellipse at latitudes greater than 90^{o} minus the declination. At the time of the equinoxes it is the straight line ef found by passing a plane through V and perpendicular to the earth's axis.

True North is found by bisecting the angle between two equal rod shadows. In the field a tip-shadow is found in the morning, the arc is drawn, the second point is found when the tip-shadow crosses the arc in the afternoon. A bead on a plumb line may be used instead of the tip of a rod.

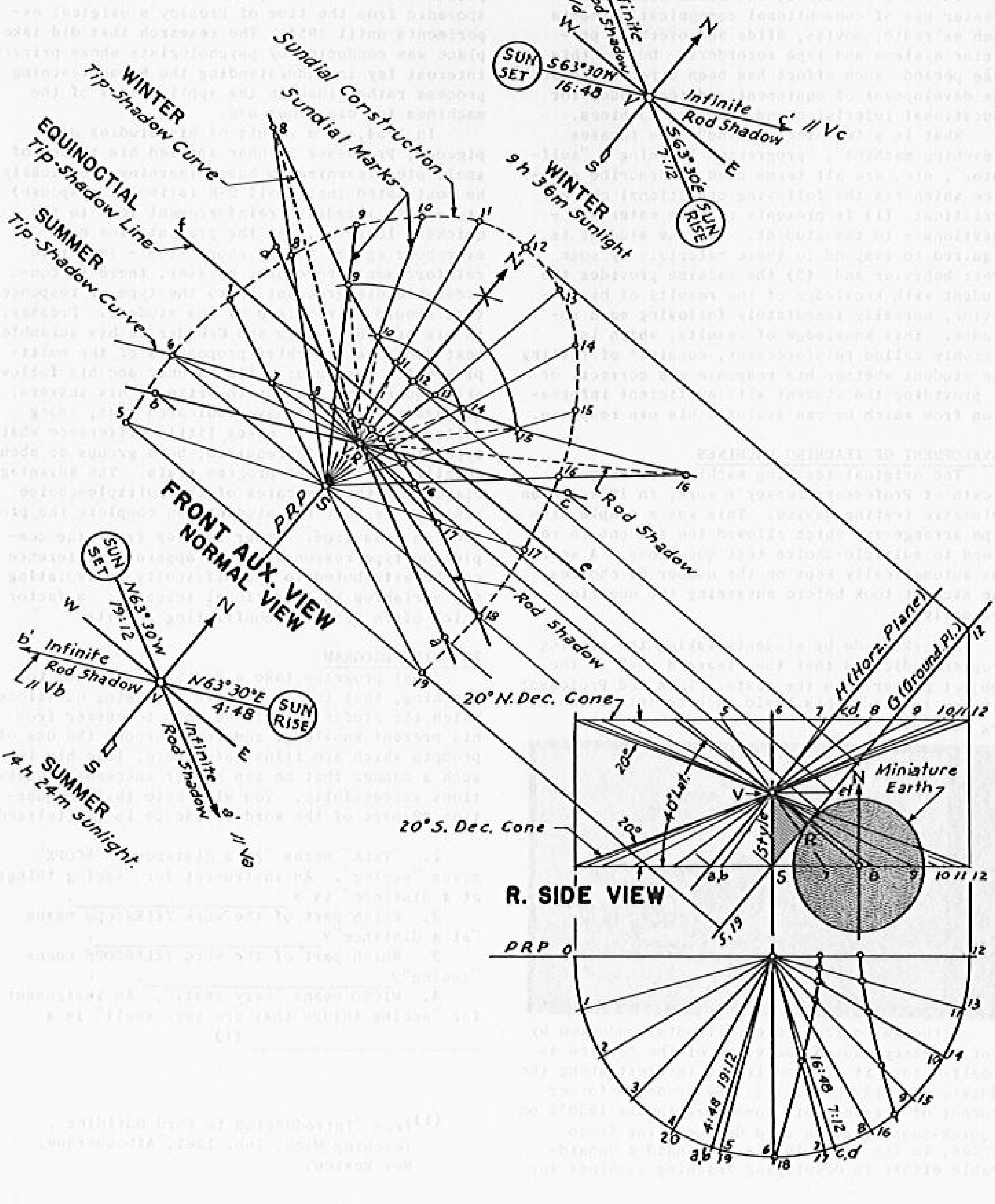
2. For the construction of a sundial in this case a section of a transparent right cylinder is used. The cylinder is coaxial with the cones and its diameter is the same as that of the bases of the cones. The cylinder has 24 elements corresponding to the elements of the cones and they are numbered likewise for the hours of the day.

A vertical triangular piece VRS is used on many sundials. The edge VS is called the style, which is parallel to the axis of the earth, and it casts shadows on a horizontal graduated dial plate. The point S and the elliptical section of the cylinder are shown in the auxiliary view for hours 5 to 19. Since the style VS is the axis of the cylinder, it will cast its shadow on the elements of the cylinder regardless of the declination. Instead of using the cylinder the dial plate at S receives the shadows of VS on the dial marks S5, S7, etc.

Since the rod tip is at V on VS, the shadows of V will fall on the sundial marks for both declinations used, and for any other declination at this latitude for which the sundial was constructed.

3. To find graphically the time and direction of sunrise and sunset a horizontal plane H is passed through the vertex of the declination cone for the day. This plane intersects the cone in the elements Vc and Vd at the time of sunrise and sunset, and it intersects the second nappe of the cone in the infinite shadows of the rod Vb and Va, which are parallel to the asymptotes of the tip-shadow curve. For clarity, since the normal view shows the elements for both 20^{o}N declination and 20^{o}S declination, these elements are redrawn parallel to the original so as to show the summer and winter results separately. The times are local sun times.

See Diagram →



Sundial Construction
Sundial Marks
WINTER Tip-Shadow Curve
EQUINOCTIAL Tip-Shadow Line
SUMMER Tip-Shadow Curve
FRONT AUX. VIEW
NORMAL VIEW
PRP
SUN SET
S63°30'W
16:48
Infinite Rod Shadow
// Vc
// Vd
Infinite Rod Shadow
S63°30'E
7:12
SUN RISE
WINTER
9h 36m Sunlight
Rod Shadow
Rod Shadow
SUN SET
N63°30'W
19:12
Infinite Rod Shadow
// Vb
N63°30'E
4:48
SUN RISE
Infinite Rod Shadow
// Va
SUMMER
14h 24m Sunlight
20° N. Dec. Cone
20° S. Dec. Cone
H (Horz. Plane)
G (Ground Pl.)
Miniature Earth
40° Lat.
Style
R. SIDE VIEW
PRP

M. N. Besel and E. W. Knoblock
University of Wisconsin, Milwaukee

INTRODUCTION

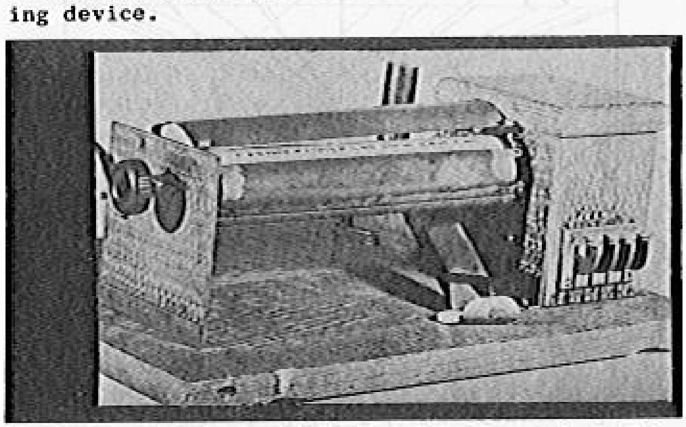
In the past decade, educators have made greater use of conventional communication media such as radio, movies, slide and overhead projector systems and tape recorders. During this same period, much effort has been directed toward the development of equipment and techniques for educational television and teaching machines.

What is a teaching machine? The phrases "teaching machine", "programmed learning", "self-tutor", etc. are all terms used to describe a device which has the following operational characteristics: (1) It presents problem materials - questions - to the student. (2) the student is required to respond to these materials by some overt behavior and (3) the machine provides the student with knowledge of the results of his behavior, normally immediately following each response. This knowledge of results, which is commonly called reinforcement, consists of telling the student whether his response was correct, or of providing the student with sufficient information from which he can evaluate his own response.

DEVELOPMENT OF TEACHING MACHINES

The original teaching machine was an outgrowth of Professor Pressey's work, in 1924, on an automatic testing device. This was a simple drum type arrangement which allowed the student to respond to multiple-choice test questions. A score was automatically kept on the number of choices the student took before answering the question correctly.

Remarks made by students taking the testing program indicated that they learned much of the subject matter from the tests. This led Professor Pressey to change his basic machine into a teaching device.



Although controlled experiments conducted by Prof. Pressey showed the value of the machine as a self-tutor, it created little interest among the educators or psychologists. Peterson, a former student of Pressey, did some work in the 1930's on a quick-scoring punch card device. The Armed Forces, in the early 1950's, expended a considerable effort in developing teaching machines for their training programs. This effort, with the results it produced, was responsible for the interest shown by educators and psychologists at the present time. However, the work in this area was sporadic from the time of Pressey's original experiments until 1954. The research that did take place was conducted by psychologists whose primary interest lay in understanding the human learning process rather than in the applications of the machines for classroom use.

In 1954, as a result of his studies of pigeons, Professor Skinner applied his theory of small step learning to human learning. Basically he postulated that small S-R (stimulus-response) steps with immediate reinforcement lead to the quickest learning. At the present time most everybody agrees to the short step - immediate reinforcement procedure; however, there is considerable disagreement as to the type of response that should be required of the student. Pressey, in his original works and Crowder in his scrambled text book are the chief proponents of the multiple-choice response; while Skinner and his followers require the student to write in his answers. Comparative studies have indicated that, among college students, it makes little difference what type of response is required; both groups do about equally well on post-program tests. The advantage claimed by the advocates of the multiple-choice response is that the student can complete the program in less time. Other studies favor the completion type response. This apparent difference can be attributed to the difficulty in isolating the variables in educational research; a factor which often leads to conflicting results.

TEACHING PROGRAM

Most programs take a Socratic approach to teaching, that is, they begin by asking questions which the student should be able to answer from his present knowledge and then through the use of prompts which are illustrated here, lead him in such a manner that he can answer succeeding questions successfully. You will note that in question #2 part of the word telescope is capitalized,

1. "TELE" means "at a distance", "SCOPE" means "seeing". An instrument for "seeing things at a distance" is a ____________________.
2. Which part of the work TELEscope means "at a distance"? ____________________.
3. Which part of the word TELESCOPE means "seeing"? ____________________.
4. MICRO means "very small". An instrument for "seeing things that are very small" is a ____________________ (1)

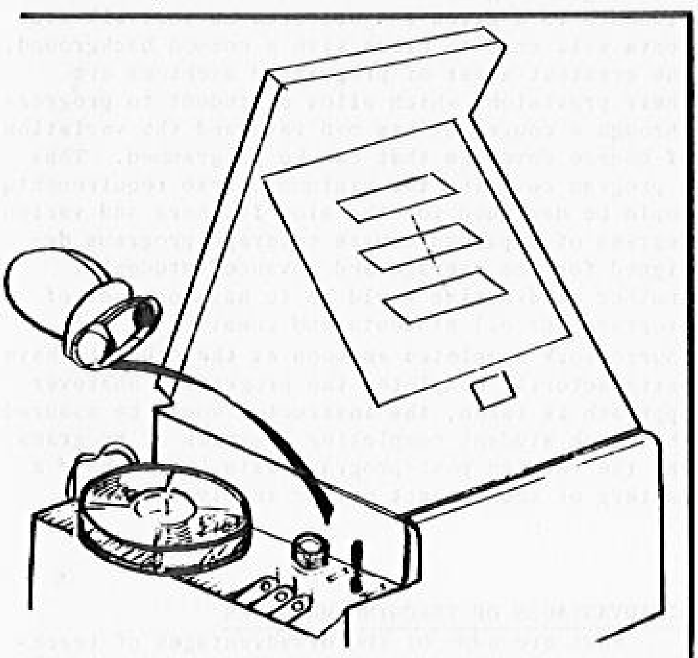
(1) from "Introduction to Word Building", Teaching Mach. Inc. 1961, Albuquerque, New Mexico.

this is a prompt that leads the student to emit the correct response. You will also note that the sequence of steps is such that the student should be able to answer all questions as he proceeds through the program. Again, one must remember that the student's answer is reinforced at each step so that he knows the correct response. To our knowledge, little work has been done on the lecture-question type program such as we are using in our research program. From the foregoing it can be ascertained that the most important problem concerning teaching machines is not the machine, but the programs that are put into it. This is emphasized by the fact that there are numerous pieces of hardware, but very few commercially available programs. At last count, there were some 81 programs on the market, but about 70 of these are only to be used for research purposes.

UW-M TEACHING MACHINE PROJECT

Our program is based upon the classroom lectures, given by our engineering drawing instructors, which are broken down into logical self-contained units. We feel that the advantage of the programming lies in the illustrations that go along with the taped lectures. The program is designed for the student who is having difficulty with the course and who will use it for review purposes. It is intended to design programs for the advanced students at a later date. Eventually we intend to have a complete set of programs designed to present the theory of engineering drawing to all individuals of a class. Our present time schedule might then be revised so that the students could spend an hour or two each week working through the programs, the remainder of the time would be spent in supervised work and discussions.

The machine that we are using is a prototype developed by the Lectron Corp. of America, Milwaukee, Wisconsin. It consists of a four channel tape play back unit hooked up to a 36 slide automatically controlled projector. One channel of the tape is used for controlling the slide changer; the other three channels are used for presenting the material and reinforcing the students' answers.



The sequence of events are as follows: The student inserts the tape and slide cartridges and starts the machine. By pressing either buttons A, B or C he will hear the presentation through his earphones, since the presentation is taped on all three channels. After the completion of the presentation, a question appears on a slide. Since the tape keeps on running, the student is given a predetermined length of time to answer. He responds by pressing the button conforming to the choice he has made. This changes the pick up of his earphones to channel 2, 3 or 4 where, after the timed interval is up, he is told whether his response was correct or not and most important, why he was right or wrong in his choice. The next question appears on a slide and the sequence is repeated until the particular program is completed.

TYPES OF TEACHING MACHINES

We feel that our machine has an advantage over most of the other machines on the market because it is multi-sensory. The student hears and sees the material being presented. The majority of teaching machines presently available are monosensory, requiring the student to read through the program. However, there are other multi-sensory machines; more refined and more costly than ours.

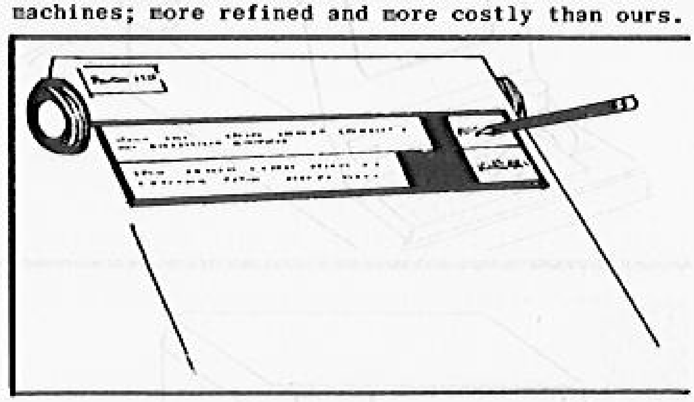
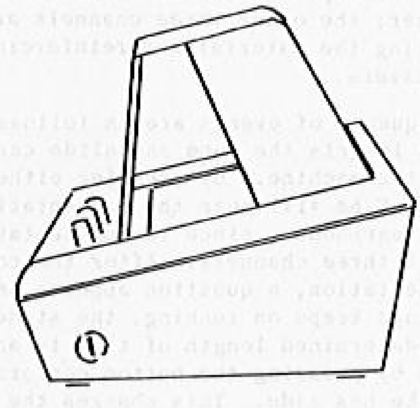
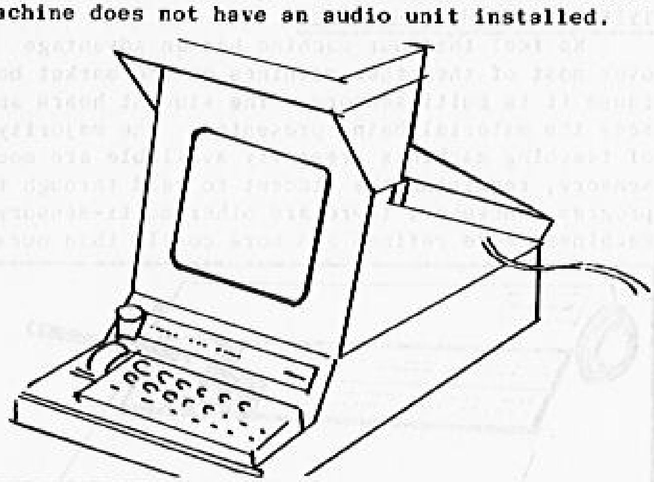


Figure 3 shows a Skinner type device. It is manually operated with a typewriter roller action to advance the program and the separate answer tape. In this case two questions appear at the same time. The top question is the one the student has just answered, with the correct answer revealed above the step in the mask and the student's answer hidden under the plastic cover so that he cannot change it. The bottom question is the one the student is answering, with the answer hidden under the mask.

The Atronic Tutor is shown in figure #4 and is a multiple choice type machine. Pressing the correct button allows the test page to drop by gravity and reveals the next question. The test page does not drop until the student has pressed the correct answer button.



The film tutor in figure #5 presents its program on a screen. The student has a typewriter-like keyboard with which he makes his response. The answers are automatically evaluated and the correct answer revealed on the next frame. This machine does not have an audio unit installed.



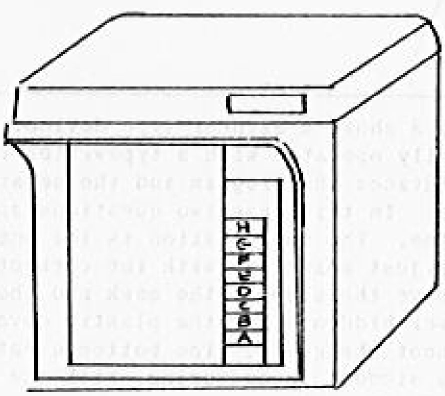
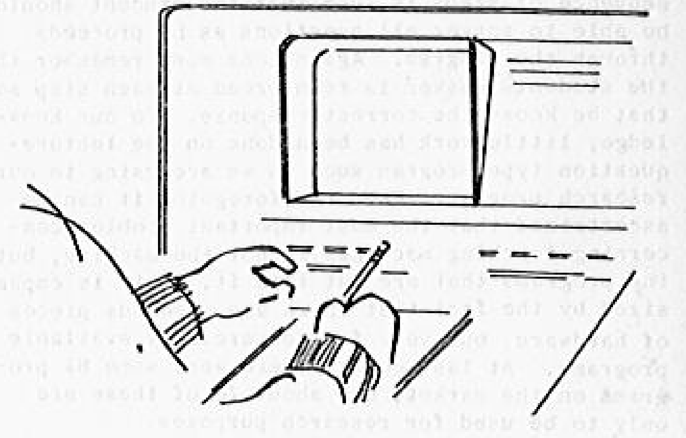


Figure #6 is an illustration of a machine that uses film strips. In this case the student responds to multiple choice questions.



The Williams "Science Desk" seen in figure #7 is a multi-sensory machine, with vidio and audio units. The film can be coded for automatic scoring and the machine is adjustable.

ADVANTAGES OF TEACHING MACHINES

It is too early in the history of teaching machines to make any positive statements as to their advantages. However, experimental evidence shows that they will increase in the amount of knowledge or skills learned over a given time period or conversely that it takes about one third less time to learn a given amount of materials with this method compared to conventional presentations. In addition, the material that the student learns can be more meaningful because he can be shown practical applications of what he is learning. Programs can be used to introduce the students to a given subject area so that all students will come to class with a common background. The greatest asset of programmed machines are their provisions which allow a student to progress through a course at his own rate and the variation of course coverage that can be programmed. Thus a program covering the minimum course requirements could be designed for the slow learners and various degrees of expanded course coverage programs designed for the average and advanced students. Another alternative would be to have one set of programs for all students and considering the course work completed as soon as the students have satisfactorily completed the programs. Whatever approach is taken, the instructor would be assured that each student completing a series of programs and the related post-program tests, would have a mastery of the subject matter involved.

DISADVANTAGES OF TEACHING MACHINES

What are some of the disadvantages of teaching machines or programmed learning? One, of

course, is the initial cost of the machines that would be required. This cost ranges from about $1.50 for a card board Skinner type machine to about $24,000 for a multi-channel, random selection slide projector to the still more complicated systems controlled by computors. Secondly, there is the amount of time spent in developing a particular program. As an example, the program which you will see required approximately 300 hours of work. Although we expect to reduce this by half in future programs, it still represents a considerable expenditure of time.

SUMMARY

The teaching machine holds a very controversial position in education at the present time. Much experimental research has been completed and the number of projects in this area are mushrooming. All the research reflects a positive indication that the influence of the machines upon the classrooms could be tremendous. But as with all teaching aids, there seems to be reluctance on the part of instructors to make use of this new technology. In arguments concerning teaching machines, you hear such statements as "they will mechanize education", or "you lose the traditional contact that the instructor has with the pupil", or "it will tend to make education too uniform throughout the country". I believe that these are the same arguments that are posed against any revolutionary concept. Institutions of higher education today are under pressure to teach more content to a greater number of students. Teaching machines and programmed learning can be a tremendous aid in meeting this challenge.

Professors Mayhew and Johnson of the Department of Mechanical Engineering of the University of Utah report in The Journal of Engineering Education, Vol.50 No. 1. that some of the potential advantages of the machine appear to be (1) Reduction of faculty lecture time, permitting increased faculty-student counselling time. (2) Reduced educational cost per instruction unit. (3) Freedom from present course scheduling problems, and (4) Students proceed at their own pace. Their program consisted of a unit on column failure. Other research programs at universities throughout the country are showing the same results. The aforementioned arguments against the use of the machines simply are not valid. The question is not whether technology will eliminate the teacher, but rather will the teacher eliminate technology? Here is a challenge and an opportunity for all of us in education and it is a challenge that all of us will have to face.

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3. Rigney, J. W., and Fry, E.B. "Current Teaching-Machine Programs and Programming Techniques", Audio Visual Communication Review, Vol. 9, No. 3, May-June 1961.

4. Meierhenry, W. C., "Learning Theory and AV Utilization", Audio Visual Communication Review, Vol. 9, No. 5, Sept.-Oct. 1961.

5. Roe, A., "Research on Teaching Machines and Programmed Learning". Paper presented at 1961 Annual Meeting of the Amer. Soc. of Engr. Educ., Lexington, Ky.

AMERICAN SOCIETY FOR ENGINEERING EDUCATION
DIVISION OF ENGINEERING GRAPHICS
PROGRAM FOR THE SUMMER SCHOOL
JUNE 14 - 16, 1962
UNITED STATES AIR FORCE ACADEMY
COLORADO

June 14, 1962
Thursday
8:00 - 10:00 PM

GENERAL SESSION: Engineering Graphics for the Future

Moderator:
Carson P. Buck
Syracuse University

1. "A New Role for Engineering Graphics Education".

Speaker: William A. Felling, Raytheon Co.

2. What of the Future?
Panel: Mary F. Blade — The Cooper Union
Edward Jacunski — University of Florida
James S. Rising — Iowa State University
John T. Rule — Massachusetts Institute of Technology

3. Discussion from the floor.

June 15, 1962
Friday
9:00 AM - 12:00 N

WORKSHOP NO. 1
Elementary Nomography
Given in drawing room - limit 25.

Leader:
Norman Arnold
Purdue University

WORKSHOP NO. 2
Basic Graphical Mathematics
Given in drawing room - limit 25.

Leader:
Robert D. LaRue
Colorado State University

WORKSHOP NO. 3
Closed Circuit Television

Leader: Conner C. Perryman, Texas Technological College

WORKSHOP NO. 4A
Teaching Machines in Engineering Graphics

Leader: Michael N. Besel
University of Wisconsin-Milwaukee

Assisted By:
Donald Dobeck — Lectron Corp. of America
Edward W. Knoblock — University of Wisconsin-Milwaukee
Maximum group 40

WORKSHOP NO. 5
Administration of Courses - The Objectives and Content of Engineering Graphics Courses.

Leader:
Melvin L. Betterley
State University of Iowa

Recorder:

June 15, 1962
Friday
1:30 - 4:30 PM

WORKSHOP NO. 6
Advanced Nomography
Given in drawing room, limit 25.

Leader:
Alexander S. Levens
University of California

WORKSHOP NO. 7
Advanced Graphical Mathematics
Given in drawing room, limit 25.

Leader: Robert H. Hammond
United States Military Academy

WORKSHOP NO. 4B
Teaching Machines in Engineering Graphics

Leader: Michael N. Besel
University of Wisconsin-Milwaukee

Assisted By:
Donald Dobeck — Lectron Corp. of America
Edward W. Knoblock — University of Wisconsin-Milwaukee
Maximum group 40

	WORKSHOP NO. 8 Descriptive Geometry - Some Advanced Problems for Engineers Given in drawing room, limit 25.	Leader: Mary F. Blade The Cooper Union
	WORKSHOP NO. 9 Administration of Courses - Advanced Courses in Engineering Graphics, Objectives? Content? For Whom? Recorder:	Leader: Ralph E. Lewis, Duke University
June 15, 1962 Friday 8:00 - 9:00 PM	**DISCUSSION SESSIONS:** "What I teach about ______." "How I teach ______."	
	Leaders: Earl D. Black	General Motors Institute
	Harold B. Howe	Rensselaer Polytechnic Institute
	Edward W. Jacunski	University of Florida
	C. Albro Newton	University of Tennessee
	Alfred J. Philby	The Ohio State University
	Recorders:	
June 16, 1962 Saturday 9:00 - 12:00 N	**WORKSHOP NO. 1** Elementary Nomography Given in drawing room, limit 25.	Leader: Norman Arnold Purdue University
	WORKSHOP NO. 2 Basic Graphical Mathematics Given in drawing room, limit 25.	Leader: Robert D. LaRue Colorado State University
	WORKSHOP NO. 10 The Computer and Engineering Graphics (This Workshop will begin at 8:30 AM)	Moderator: Ernest J. Weidhaas Pennsylvania State University
	Leader: Forest M. Woodworth	University of Detroit
	Assisted By: Charles J. Baer	University of Kansas
	James R. Burnett	Michigan State University
	James Houghton	University of Notre Dame
	William J. Quirk	U.S. Air Force Academy
	Earl C. Zulauf	University of Detroit
	This program will assume little or no experience with computers - Limited to 48 by equipment.	
	WORKSHOP NO. 3 Closed Circuit Television	Leader: Conner C. Perryman Texas Technological College
	Assisted By: Lee C. Lindenmeier	Texas Technological College
	Oliver M. Stone	Case Institute of Technology
	WORKSHOP NO. 11 Projective Geometry in Engineering Graphics. Given in a drawing room, limit 25.	Leader: V.P. Borecky University of Toronto

June 16, 1962 Saturday 1:30 - 4:30 PM	**WORKSHOP NO. 6** Advanced Nomography Given in drawing room, limit 25		Leader: Alexander S. Levens University of California
	WORKSHOP NO. 7 Advanced Graphical Mathematics Given in drawing room, limit 25		Leader: Robert H. Hammond U.S. Military Academy
	WORKSHOP NO. 10B The Computer and Engineering Graphics Workshop 10A for beginners will be repeated for a limited group of 16.		Moderator: Ernest J. Weidhaas Pennsylvania State University
	Advanced course for those who completed the morning program Workshop 10A and others who have had some experience with computers.		Moderator: James S. Rising Iowa State University Leader: Forrest M. Woodworth University of Detroit
	Assisted by: Charles J. Baer James R. Burnett James Houghton William J. Quirk Earl C. Zulauf		 University of Kansas Michigan State University University of Notre Dame U. S. Air Force Academy University of Detroit
	Limited by equipment to 48		
	WORKSHOP NO. 12 Overhead Projection Assisted by: Richard P. Covert Emil W. Grieshaber John B. Hawley M. E. Warner		Leader: Klaus E. Kroner University of Massachusetts University of Missouri Minnesota Mining and Manufacturing Company Arizona State University Washington Senior High School, Cedar Rapids, Iowa
	WORKSHOP NO. 13 Tests and Test Analysis Assisted by: H. Lamar Aldrich Wayne Felbarth Richard C. Kohler Raymond A. Kliphardt Ivan W. Roark William B. Rogers		Leader: Irwin Wladaver New York University University of Dayton University of Detroit University of Illinois-Navy Pier Northwestern University University of Tulsa U.S. Air Force Academy
June 16, 1962 Saturday 6:30 PM	DINNER	OFFICER'S CLUB	Presiding: Edward M. Griswold The Cooper Union
		Presentation of Awards Descriptive Geometry Award Nomography Award Distinguished Service Award	
		Speaker B. Leighton Wellman	Worcester Polytechnic Institute

ONE OF THE WORKSHOPS WILL BE AS FOLLOWS:

WORKSHOP NO. 10 ON COMPUTERS

Introductory Sessions - For the Beginner

Presiding:
Professor Ernest Weidhaas
Pennsylvania State University

Note: While other workshops are scheduled to begin at 9:00 A.M., this one is scheduled for 8:30 A.M. Participants are asked to make suitable breakfast arrangements, and be prompt. The workshop is on a first-come, first-served basis for those expressing this workshop as their preference during pre-registration. Only 48 participants will be admitted.

8:30 A.M. Lecture I.
Introduction to Analog Computer Programming.
Professor James Houghton, University of Notre Dame

9:00 A.M. Demonstration I.
Patching a Problem on the Computer
Captain William J. Quirk, U.S. Air Force Academy

9:25 A.M. Break

9:30 A.M. Problem Session I.
Practice in the Programming and Patching of one or more simple problems.
Staff

Note: Captain Quirk has offered the use of 24 small analog setups; therefore the group will work in "twos" for the actual patching of the problems.

10:55 A.M. Break

11:00 A.M. Symposium

Professor Weidhaas, Moderator

Participants: (In order of appearance)

Captain Quirk, on "Introducing analog Programming"*

11:15 A.M.
Professor F. M. Woodworth, University of Detroit "Graphics and the Analog Computer".

11:30 A.M.
Professor Charles Baer, University of Kansas, on "The Digital Computer"*

11:45 A.M.
Questions and Discussion

*Exact topic title to be the prerogative of speaker.

Note: The purposes of the symposium are:

1. Suggest efficient ways to introduce students to the analog computer (Captain Quirk).

2. Tie the subject in with Engineering Graphics (Professor Woodworth).

3. Draw comparisons between analog and digital computers (Professor Baer).

12:00 N Lunch Note: In order to make most efficient use of the time available, everyone is requested to eat promptly and be ready for the afternoon sessions.

- Afternoon -

Introductory Sessions: (Labelled I). For the Beginner

Presiding: Professor James Rising, Iowa State University, at Sessions Labelled I.

Note: These sessions will be limited to 16 participants.

Continued Sessions: (Labelled II). A Continuation of the morning sessions.

Presiding: Professor Weidhaas, at Sessions Labelled II.

Note: These sessions will run concurrently with the afternoon introductory sessions, and limited to 48 participants. Priority will be given to those who attended themorning sessions.

1:00 P.M. Lecture I
Introduction to Analog Computer Programming — Professor Houghton

Lecture II
Auxiliary Analog Equipment. (Multipliers, Function, Generators, etc.) — Professor James Burnett, Michigan State University

*Exact topic title to be the prerogative of speaker.

1:30 P.M. Demonstration I.
Patching a Problem on the Computer — Professor Earl Zulauf, University of Detroit

1:55 P.M. Break

2:00 P.M. Problem Session I.
Practice in the Programming and Patching of one or more simple problems. — Staff

Note: We will use 8 of the computers, 2 participants per computer.

Problem Session II.
Practice in Programming and Use of Auxiliary equipment. — Staff

Note: Since 8 of the 24 setups will be relegated to Session I, thus leaving 16 open, 3 participants will be assigned one machine for this session.

3:25 P.M. Break

Note: Both sessions will break together, so that all participants may gather as a single group for the panel discussion.

3:30 P.M. Panel Discussion — Professor Rising, Moderator

Participants: Prof. Baer
Prof. Burnett
Prof. Houghton
Captain Quirk
Prof. Earl Ratledge, University of Wisconsin at Milwaukee
Prof. Zulauf

Topic: "Use of Analog Computers in Engineering Graphics Classes"

4:15 P.M. General Discussion

4:30 P.M. Workshop Ends

"How To Win Friends and Influence A Profession"

By Jasper Gerardi
Assistant Dean of Engineering
University of Detroit

In preparing this discussion on the Future of Engineering Graphics, I was guided by instructions from the Program Committee to present the viewpoint of the college administrators and to give a "hard-hitting analysis of future prospects in this field" based on my experience as a teacher and administrator. To make it clear, I cannot and do not propose to speak for college administrators; rather I shall express my personal opinions and viewpoints which I believe may be effective in the promotion of graphics. The words "college administrators", as used hereafter, refer to department chairmen and deans since these are the people usually responsible for or intimately involved in curricula or course content changes.

During the past few years there has been a notable change in the type and level of papers which have been presented at our meetings. In general, these papers have demonstrated rather specific applications and the power of graphics in the various branches of engineering. Emphasis has been on the versatility of graphics in engineering and not on the techniques of drawing. More recently, our guest speakers have emphasized the importance of graphics in mathematics and engineering mechanics. A few departments are now exploring the place of graphics in computer technology as reported at the 1961 Meeting at Lexington and also at this Mid-Winter Meeting.

The final details regarding our next summer school have not been completed but we know that several participants will lead discussions involving graphics as related to other disciplines in engineering sciences.

It is fortunate that this Division has been farsighted for we are beginning to get some recognition for our efforts.

In discussing the trends in engineering curricula before a group of mathematicians, Dr. Newman A. Hall, Vice-President of ASEE Instructional Division Activities, made this statement: "Drafting is entirely changed from what it used to be. There are a few schools which have no drafting requirements in their engineering curriculum, and it is accepted. Furthermore, there are very few of the engineering schools whose drafting course has not been tremendously changed, and in very few cases do you have any of the emphasis on precision, skill, and pen and ink drawing that you used to have." No doubt Dr. Hall used the word "drafting" in a broad sense because the term "graphics", as used in engineering, may not have been appreciated by the mathematicians. I am also of the opinion, or would like to believe, that at engineering colleges where drafting is not required, graphics courses are at least offered as electives.

Dr. Hall's statement is most encouraging and is bound to have some influence on engineering college administrators. It may also imply a warning to the effect that at schools where courses called graphics are, in fact, only drafting courses, there is a possibility that in time the courses may disappear from their curriculum.

It is up to each of us in this Division, and in particular up to our officers and committees, to direct our efforts in such a manner that graphics will be considered an indispensable aspect of an engineer's training. If we accept this responsibility and, in particular emphasize the versatility and power of graphics in engineering design (by this I mean engineering systems of analysis and synthesis), it should be possible to increase the support and encouragement we need from administrators in our engineering colleges.

It appears then that we must once again review and try to state the objectives of graphics in a modern engineering curriculun

Our Division's Committee on Aims and Scope has given considerable thought to this problem but I would like to suggest that in their deliberations the Committee explore further the following precepts of graphics:

1. The primary objective of graphics is to give students a versatile tool which will increase their understanding of the fundamentals of the mathematical and physical sciences as applied in engineering design.
2. An important function of graphics is to transfer the concepts involved in engineering problems into descriptive graphical elements from which actual physical and geometrical relationships can be illustrated so that appropriate mathematical and graphical manipulations can be performed.
3. Graphics is the vehicle through which correct engineering intent can be communicated to draftsmen and technicians for the development and production of things people need and want.

This attempt to define graphics is not all inclusive nor flawless but it can serve as a basis for further discussion and exploration.

We might consider "graphics" as a thinking device which is used to analyze and integrate the fundamental principles involved in engineering situations. Every engineering problem includes some mathematical computation but this symbolic manipulation is usually associated with graphical illustration of some kind. Why? Because graphical representation is the only means we have to approximate actual conditions which clearly show the interdependence or relationship between components of a structure before one can produce a mathematical model for further analysis. We must remember that despite the encroachment of the computer and its effect on engineering, so well presented by our speakers this morning, computers must be programmed. Hence, there always will remain the problem of giving proper instructions to the machine -- either in verbal, graphical, or symbolic form. It is here too, in the art of programming, that graphics can play a new role -- to aid in formulating problems so that physical concepts can be readily translated to mathematical systems.

It may appear that what has been said conflicts with Professor Steven A. Coon's warning that, "if graphics teachers relinquish their firmly held position as proponents of drawing-for-the-shop and move into an equally firm position as proponents of graphical mathematics, then they will by this action still show themselves to be hide-bound, but in a different place." Rather, I have tried to suggest the specific objectives of graphics as an integrating device which brings together disciplines in engineering instead of a device which shifts emphasis from a compartment of communication to a compartment of graphical mathematics. Moreover, won't this idea of translating scientific and mathematical knowledge into graphical models of actual engineering problems induce and develop creative mental activity? Does it not seem logical to presume that courses designed to implement these facets of graphics would meet with administrative approval?

I believe so, but I know that those whose courses are threatened with a further reduction of time, in all probability are skeptical and feel that it takes more than an implementation of these objectives to convince their administrators to keep graphics from being swept into the unknown. This may be true in a very few cases, but it would seem very doubtful that administrators would want graphics courses, which have been enriched with pure engineering flavor, removed from their curriculum. Further, I am of the opinion that unless our objectives change and change fast, engineering administrators may be justified in their attitude towards graphics.

We must remember that our Division does not have a public relations committee to extol our virtues. There is only one way to win the confidence of degree-granting department, and that is to work closely with them -- to suggest and show what graphics can do for students in the respective branches of engineering, and to be able to adjust and make changes in course content to conform with the changing demands of the profession.

It is an administrator's prerogative to set a course of action and to use his influence on faculty members in order to achieve academic stature and growth of a department or school. Administrators are usually held responsible for final decisions and, right or wrong, decisions must be made based on judgment of what is considered best for the engineering profession.

A Dean usually depends on his faculty curriculum committees to determine what is to be deleted or added to the curriculum. He may exert his influence and help to reconcile differences of opinion or promote those aspects of the curriculum which put it in line with the requirements of the profession but, in the long run, only those courses which bear a relationship to modern engineering methods will survive the extensive and heated discussions common to all curriculum committee meetings. But more important, administrators also can be easily, and usually are, influenced by faculty who are best qualified to teach their subject because of extensive training, a high degree of competence in their field, and an interest in various aspects of engineering.

I have a feeling that in some cases graphics is unintentionally absorbed into other departments because of complacency and because we tend to live in the cozy atmosphere of drawing as "the language of the engineer". It seems to me that in these days of revolution in engineering education, we should continue to show that graphics is a versatile and sophisticated subject and, as such, this subject must be taught by competent graphicists. We must also remember that more mathematics and science will permeate our engineering curricula and it is our job to transfer these disciplines into graphical models in order to solve engineering problems. You can be sure that some form of computer technology will be taught in engineering colleges and, of course, this takes time. Computers can become our best friend. It is a fact that graphical analysis can contribute to the formulation of problems in automated procedures for computers and, if we are alert, observant, and indicate a high degree of enthusiasm for new developments of this type, we may not only keep what little time is left for graphics, but possibly bring about an increase.

Hence, I believe it to be unfair to accuse college administrators if course time is reduced in certain areas. The question which must be answered is whether or not the course in question is really college level and what it contributes to an engineer's education. Why should drafting remain as a series of time-consuming coursesin an engineering curriculum when technical institutes and industrial in-service training programs produce better draftsmen than our colleges.

Granted that any similarity between many graphics courses today and those of a few years ago is purely coincidental, the fact remains that we are fighting not only tradition but an impression of long standing associated with drawing as "the language of the engineer". In general, the reason that college administrators, and for that matter executive engineers in industry, associate graphics with drawing is that, until recently, many of us have not given them strong reasons to think otherwise. Note the description of graphics courses in college catalogues. In technical magazines very often problems are solved graphically, but how often does the reader associate this with graphics especially if a few mathematical equations are included?

Lately some of us have included a study of vectors in our graphics course, but have we gone far enough in this area. All teachers of engineering mechanics will agree that vector notation is advantageous in the solution of some mechanics problems. This is particularly true in dealing with two or three dimensional vector quantities. What happened to Descriptive Geometry in this area of engineering? Has the glamor of vector and tensor notations obscured the most powerful graphical tool which can deal with spatial description of vector quantities? Would not some research in these areas help to break down the impression that graphics is only a form of communication?

May we not be creating an image of technical deficiencies in ourselves and our work if we continue to make changes in our courses at a snail's pace. Let's face it. The term "mechanical drawing" has been used so long that it has created an image which is extremely difficult to change. Merely changing the names of courses to graphics, even if more emphasis in another facet of engineering is involved, will not cause administrators to allot more time to this subject.

Graphical analysis will always be a part of an engineering student's training but, if we do not take the initiative, upgrade our course material, and do some effective research in graphics as it applies to engineering disciplines, we may find graphics taught as fragments in other departments of instruction. Should this happen, it would be a sad day and would certainly slow down academic progress in engineering.

In summing up this aspect of our discussion, I refer to recent correspondence with Dr. R. E. Fadum, an administrator and consulting engineer, who clearly and briefly states our problem in this manner: "With respect to the place of instruction of graphics in the engineering curriculum, it might be helpful first to outline what we conceive to be the fundamental objectives of an engineering education. Among these I would include the development of a student's ability to reach sound judgement values, to appreciate the importance of aesthetics, to communicate his ideas clearly and lucidly, to develop his creative talents and power of analysis and synthesis, and to acquaint him with the methodology involved in performing the design funcion. Having defined the objectives, one can then ask which of them can be served by including in the curriculum some discipline in graphics, and in this manner point to this subject matter as an important component of the curriculum".

It appears, then, that our work is cut out for us in at least three areas:

1. We must show that subject matter in graphics is an integral part of engineering education.
2. We must show that graphics has an important role in the formulation and solution of engineering problems and that it is essential to all technical subjects in an engineering curriculum.
3. Having shown its need in an engineering curriculum, we must work with other departments of instruction and, when necessary, increase our knowledge of subject matter in order to teach graphics more effectively.

It is always easy to tell another person what to do; but to implement a program, to coordinate their efforts on a national basis, and to bring results to the attention of the right people is another matter. In fact, it seems that nothing short of supernatural effort could accomplish such an objective. Well, some extraordinary events have taken place and we are now in position to take advantage of them.

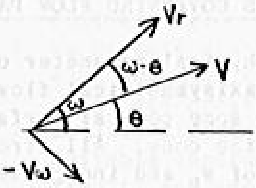
About 1958 ASEE sought and succeeded in having the National Science Foundation increase the funds appropriated for projects involving engineering education. As a result of this, in 1959 among other projects the National Science Foundation appropriated sufficient funds to support two institutes and a conference for graphics teachers. In 1960, another two-week conference for teachers of mathematics, physics and graphics was approved. Financial support was also granted for two institutes for Junior College graphics teachers. Moreover, grants have been made in the visual aids area. To date, I have not seen a report of the grants made in 1961, but I am pleased to announce that last summer the University of Detroit became the custodian of a $68,000 grant for research to find new applications of graphics in engineering. This study is to be conducted on a national basis under the direction of Professor P.M. Reinhard who will be assisted by Professor F.A. Heacock of Princeton University and Professor A.S. Levens of the University of California at Berkeley.

Please note the words, "custodian of a grant", which were used deliberately from the inception of the idea in 1959, there never was the remotest idea that this is to be a University of Detroit project. It was intended and, for all practical purposes, will remain a Graphics Division project.

Before giving further details of this project, may I explain the reason for not publicizing our efforts. Frankly, our reason was selfish. Neither Professor Reinhard nor I wanted to associate ourselves or the Division with a project which had no possibility of succeeding without financial support.

A proposal was submitted to the National Science Foundation in the Spring of 1960, and work was to have begun in September, 1960. You can imagine how we felt when no word had been received by June, 1960, for we had hoped to announce the results of our efforts at the Annual Meeting at Purdue. Another year rolled by. We had all but given up hope when, a few days before the Annual Meeting at Lexington, we were informed that Dr. Paulson and Dr. Whitmer of the National Science Foundation would be pleased to meet with us at the Lexington Meeting. Professor Reinhard immediately went to work, arranged a breakfast meeting, and prepared an agenda for discussion. In July, 1961, the project was approved.

The derivation of the governing equation (e.g. Ref. 3 pp. 654-656 is accomplished using spherical coordinates r and ω. The components of velocity are as follows:



The velocity equation in terms of V_r is then:

$$- \frac{d^2V_r}{d\omega^2}\left[\frac{k+1}{2}\left(\frac{dV_r}{d\omega}\right)^2 - \frac{k-1}{2}\left(V_{max}^2 - V_r^2\right)\right] - \frac{k-1}{2} x$$

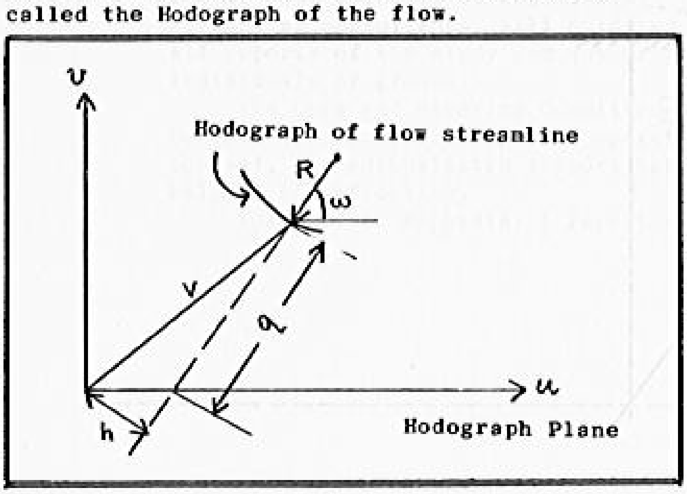
$$\left(\frac{dV_r}{d\omega}\right)^3 \cot^{\omega} - kV_r\left(\frac{dV_r}{d\omega}\right)^2 + \frac{k-1}{2}\left(V^2_{max} - V_r^2\right) x$$

$$\frac{dV_r}{d\omega} \cot_{\omega} + (k-1)\, V_r \left(V^2_{max} - V_r^2\right) = 0$$

where K is the ratio of specific heats and V_{max} is the maximum velocity attainable (all fluid energy converted into kinetic enery of flow)

This non-linear equation would normally be solved using a numerical integration procedure. However, the following graphical construction taken from Ref. 3, pp. 657-659, which was published by Busemann in 1929, has the advantage of retaining a physical picture of the flow during the construction.

The construction of a flow field obtained by mapping the velocity vector for various points in the flow. Each velocity vector begins at the origin of the Hodograph Plane. The curve described by the tip of the vector as it rotates to indicate the velocity throughout the flow is called the Hodograph of the flow.



The construction procedure is based on the following equation derived by Busemann giving the local radius of curvature of the streamline hodograph.

$$R = \frac{q}{1 - \frac{2h^2}{(k-1)(V^2_{max} - V^2)}}$$

where h, g and V are shown in the above sketch.

GRAPHICAL SOLUTION FOR FLOW PAST A CONE

The construction is shown in Figure 2 and begins with the plotting of a shock polar for the particular free stream Mach number chosen. The necessary data were obtained from Ref. 5, p. 430-1. Next the angle of the shock σ is laid off establishing point 2 just inside the shock. The radius of curvature of the Hodograph is now calculated from the preceding equation and a small arc (2° arcs were used in Fig. 2) is drawn. A new radius is calculated for the next small arc. Note that the radius of curvature line, at generally angle W, represents the angular position of the ray of constant properties having the properties represented by the corresponding point in the Hodograph. The construction is continued until the radius of curvature line intersects the origin. Then ω = s the vertex angle of the cone indicating that the endpoint of the streamline Hodograph has been reached.

The construction was made with a, the initial sound speed represented by 1 inch in length. The velocity vectors represented by the hodograph are therefore V/a, inches in length. To obtain flow properties, the Mach number can be found from:

$$M_x^{\,2} = \frac{1}{\left(\frac{a_{xo}}{V_x}\right)^2 - \frac{k-1}{2}}$$

where a_{xo} is the stagnation sound speed of the flow. Since the value of a_{xo} is everywhere the same inside the shock the value a_{2o} may be used. Note that

$$\frac{a_{2o}}{V_x} = \frac{1}{\left(\frac{V_x}{a_1}\right)\left(\frac{a_1}{a_2}\right)\left(\frac{a_2}{a_{2o}}\right)}$$

Vx/a, is the measured value and a_1/a_2 and a_2/a_{2o} are constants determined by conditions at the shock. When the Mach number and flow angle θ

are known, all flow properties may be obtained from tables and charts for the shock flow.

The basic results are given below:

Cone angle	36.8°
Shock angle	44.75°
Pressure at cone surface	9.55 times

free stream pressure

Note that the construction began by choosing the shock angle (approx. 45°) and the cone surface angle was subsequently obtained. The reverse problem can be solved but a few trial solutions may be necessary (See Ref. 4).

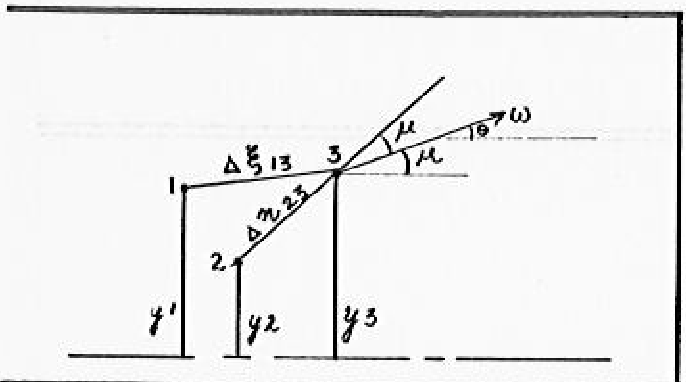
The Method of Characteristics

The characteristic equations for axially symmetric, nonviscous flow are (Ref. 5, p. 293):

$$\frac{\partial}{\partial \eta}(\nu - \theta) = \sin\mu \, \frac{\sin\theta}{y}$$

$$\frac{\partial}{\partial \xi}(\nu + \theta) = \sin\mu \, \frac{\sin\theta}{y}$$

where η and ξ are characteristic coordinates. ν is the Prandtl-Meyer function, a dimensionless parameter related to speed, and θ is the flow angle. μ is the Mach angle and y is the radial distance from the axis to the point in question.



The solution of these equations must be done step by step simultaneously with the construction of the characteristics network. For example, the flow parameters at some downstream point 3 can be obtained from known data at points 1 and 2. If the Mesh size is small the solution of the characteristic equations may be written:

$$\nu_3 = \tfrac{1}{2}(\nu_1 + \nu_2)\ \tfrac{1}{2}(\theta_1 - \theta_2) + \tfrac{1}{2}\left(\sin\mu_1 \frac{\sin\theta_1}{y_1}\Delta\xi_{13} + \sin\mu_2 \frac{\sin\theta_2}{y_2}\Delta\eta_{23}\right)$$

$$\theta_3 = \tfrac{1}{2}(\nu_1 - \nu_2) + \tfrac{1}{2}(\theta_1 + \theta_2) + \tfrac{1}{2}\left(\sin\mu_1 \frac{\sin\theta_1}{y_1}\Delta\xi_{13} - \sin\mu_2 \frac{\sin\theta_2}{y_2}\Delta\eta_{23}\right)$$

The construction is shown in Figure 3. The angle μ between the flow direction and the direction of the characteristics is obtained initially at points 2 to 6 using tabulated values (Table V of Ref. 5) corresponding to the cone solution Mach numbers. For later points the same table is used to obtain the Mach numbers (and subsequently and desired flow properties) from the calculated values of ν.

Note that the locations of the new points are not known in advance but are determined by the intersection of characteristics from two different preceding pi
preceding points. Special techniques are needed at boundary points where only one characteristic is available. At the cone surface, e.g. point 7, the flow is tangent to the surface, so θ, is known. The value of ν_7, is found from the following equation.

$$\nu_7 + \theta_7 = \nu_5 + \theta_5 + \sin\mu_5 \, \frac{\sin\theta_5}{y_5}\Delta\xi_{57}$$

As the construction continues the net may become too coarse. A new point such as 11 in Figure 3 may be generated using interpolated properties from points 2 and 10. At point 12, a boundary point on the shock front, again only one characteristic is available. The solution is obtained by matching one of the possible Mach number and flow angle combinations just inside the shock front (Chart 2, Ref. 5) with the remaining condition:

$$\nu_{12} - \theta_{12} = \nu_{11} - \theta_{11} + \sin\mu_{11} \, \frac{\sin\theta_{11}}{y_{11}} \, \Delta\eta_{11\text{-}12}$$

The flow direction at each point is shown in Figure 3. Also the flow direction along any ray can be obtained from Figure 2 for the region of influence of the cone. It is therefore possible to draw any particle path by fairing in a curve parallel to the flow directions which are known along the rays and at the net points.

The flow solution may be continued for any axisymmetrical afterbody, but sharp edges and the possibility of terminal shocks or vorticies require treatment.

Figure 2 - Graphical Construction in the Hodograph Plane for Flow Past a Cone.

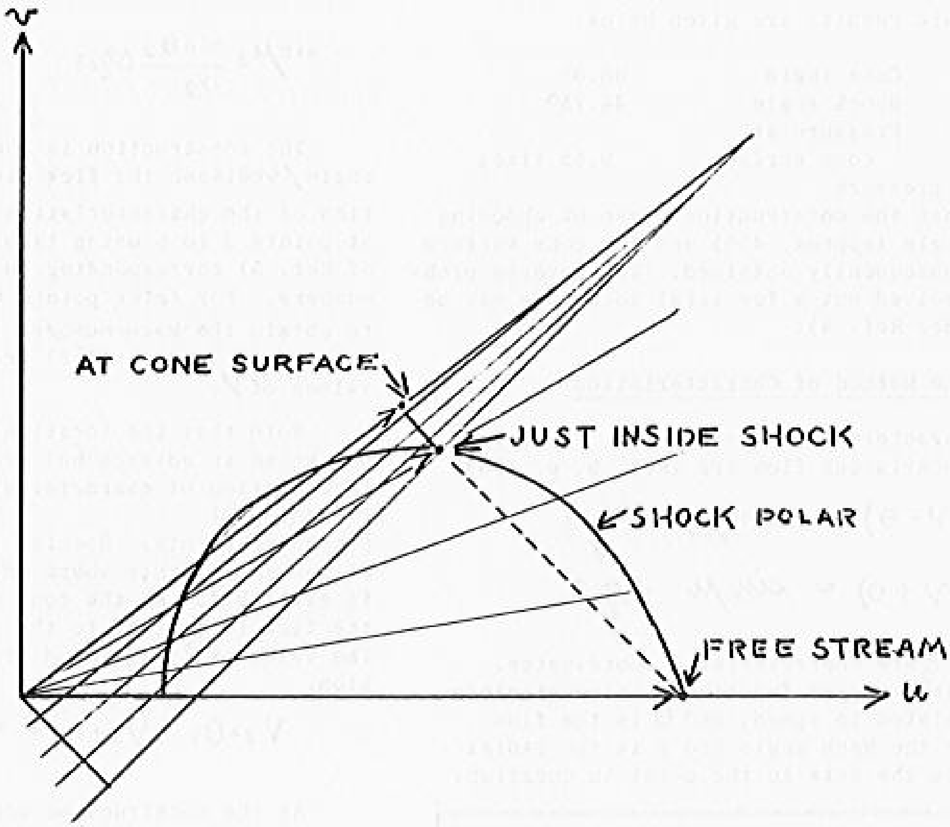


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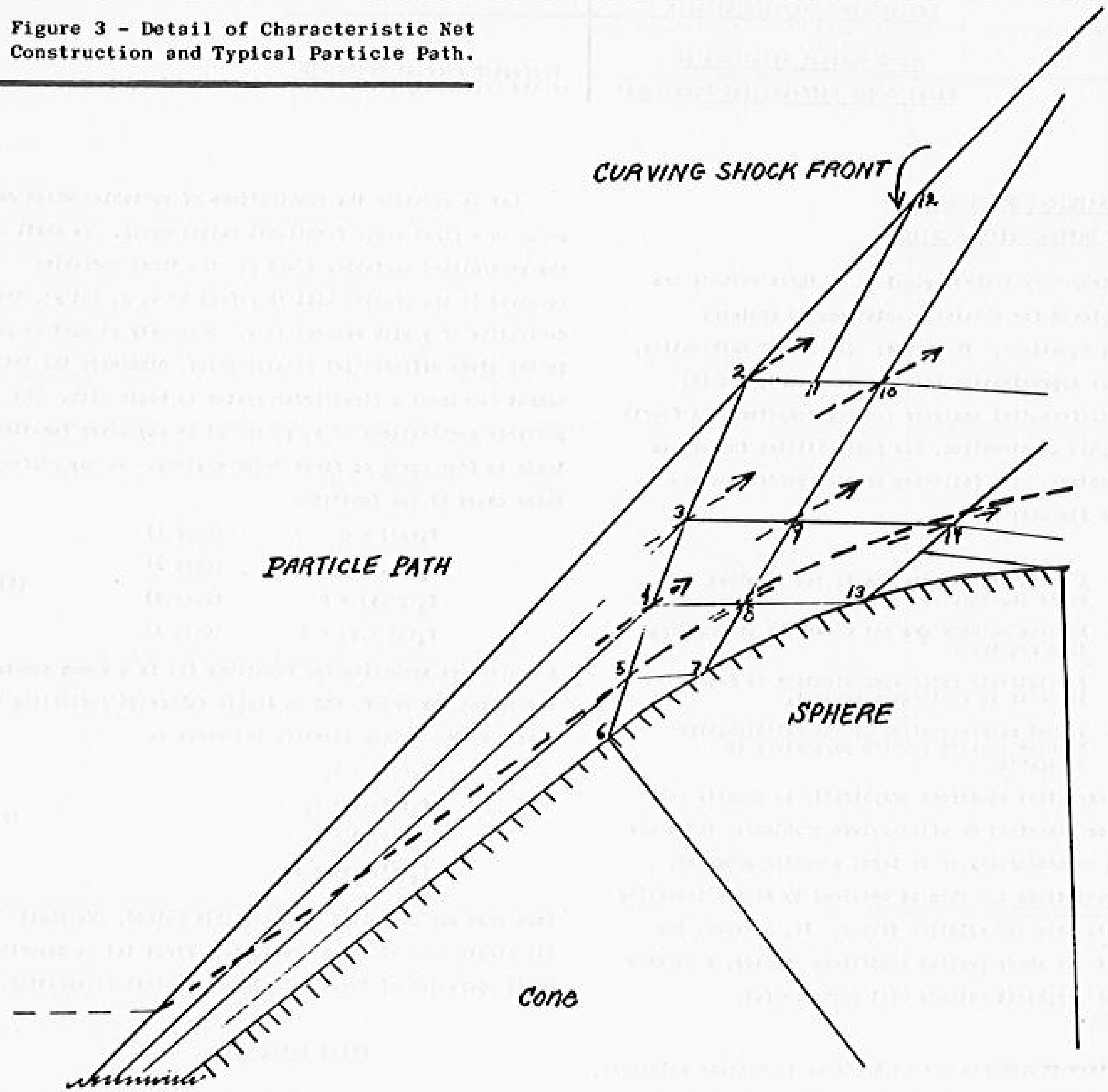
Figure 3 - Detail of Characteristic Net Construction and Typical Particle Path.



ACKNOWLEDGEMENT

It is especially appropriate in this publication of the American Society for Engineering Education to acknowledge the well prepared and presented lectures of Professor P.A. Thompson of R. P. I. in whose class on High Velocity Flow the author obtained the necessary background to be able to solve problems of the type here presented.

ENGINEERING GRAPHICS SEMINAR

"On Graphical Solutions of First Order Differential Equations"

Professor Forrest Woodworth
of the University of Detroit

THE GRAPHICAL SOLUTION OF FIRST ORDER DIFFERENTIAL EQUATIONS

In contemporary technological work, three methods are commonly employed for obtaining solutions to ordinary differential equations. These are: (1) formal mathematics, (2) numerical approximation (digital computer), and (3) electronic differential analyzer (analog computer). A fourth method, graphic construction, has possibilities in certain types of problems. The following problem conditions are conducive to its use:

(1) A mathematical solution is too involved or is impossible.

(2) Machine methods are not worth the programming time required.

(3) A relatively rapid approximation is needed in order to continue a project.

(4) Visual representation of the relationships between various problem parameters is desirable.

Solving differential equations graphically is usually not practical for classical or often-solved problems; these are best solved by nomography or by taped computer programs. Particular solutions can then be obtained by simply inserting a set of data into the solution device. If, however, one (or more) of the above problem conditions applies, a working knowledge of graphical methods will prove useful.

Iterative procedures are no handicap to machine solutions, but are awkward in graphical work. Progress has been made toward eliminating the necessity of using iteration in the graphical solution of differential equations. Some time ago, research into this problem eliminated iteration from the integration proper for every case of first order equations. More recently this has been duplicated, although with considerably more effort, for all cases of second order equations. Such simplifications do not guarantee freedom from iteration in graphical processes related to the solution of differential equation problems. But by making the integration more efficient, they reduce the probability of an iterative requirement. The sample problems selected for this presentation are relatively simple and involve only first order systems. All have non-iterative solutions.

Let us consider the combinations of variables which can occur in a first order functional relationship. We shall use the generalized variables x and y; the three variables involved in the problem will therefore be x, y, and y', the derivative of y with respect to x. Obviously y' must be present in the given differential relationship; otherwise the latter cannot represent a first order system to begin with. The possible combinations of x, y, and y' in any given function leads to four cases of first order systems. We may represent these cases by the functions

$$\begin{aligned} f_1(y') &= 0 \qquad &\text{(Case 1)}\\ f_2(y',x) &= 0 &\text{(Case 2)}\\ f_3(y',y) &= 0 &\text{(Case 3)}\\ f_4(y',x,y) &= 0 &\text{(Case 4)} \end{aligned} \qquad (1)$$

A convenient symbolism for equations (1) is a Roman numeral indicating the order, and an Arabic subscript indicating the case. We would then identify the cases as

$$\begin{aligned} f_1(y') &= I_1\\ f_2(y',x) &= I_2\\ f_3(y',y) &= I_3\\ f_4(y',x,y) &= I_4 \end{aligned} \qquad (2)$$

Each case can be solved by a suitable method. We shall illustrate each of these presently. First let us describe the basic operation of these methods - graphical integration.

Field Integration

Various ways of performing graphical integration are available. A particularly useful one is a field method which employs mutually perpendicular phase, slope, and solution planes. These planes are shown orthographically in Fig. 1. If the solution plane is considered to be horizontal, then slope planes are frontal and phase planes are profile. With first order equations, all planes are 2-dimensional; with second order and higher systems, the slope and solution planes are each 2-dimensional, while the phase plane is (n+1)-dimensional, n being the order of the system.

In Fig. 1, O is the origin, and the axes are oriented according to the rules of 3-dimensional orthographic projection. Distance $\overline{OP}$ is considered to be unity (it may not actually be), and P is known as the pole. If $\overline{OP}$ is other than the x axis unit length, the ratio of unit length along the y axis to unit

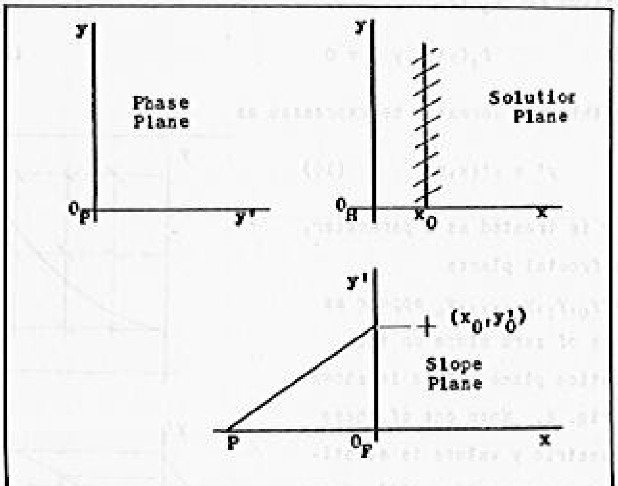


Fig. 1

length along the y' axis will be the same as the ratio of unit length along the x axis to the distance $\overline{OP}$. Therefore, if we assume that the y' axis has been graduated according to the confines of the problem, the graduations on the y axis will be determined by the selection of P, and this in turn will be restricted by the height to which the curve rises on the solution plane.

The y' ordinate for any x is the slope value of the xy curve at that point. But since the general solution of an ordinary first order differential equation contains a constant of integration, the slope represented by y' could be the slope of an infinite number of curves, at that value of x. Therefore, if we draw a series of slope lines on the solution plane, parallel to PA and along $x = x_0$, we create a field representing the general solution for (x_0, y'_0). Since there are, theoretically, an infinite number of these parallel lines, a particular solution which is defined for this value of x must include one of them. Note that every curve on the slope plane will result in an entire field on the solution plane.

Case 1

We may call I_1 the linear case, because its general solution is

$$y = mx + b \tag{3}$$

where m represents any particular solution of $f_1(y') = 0$, and b is the constant of integration. The method of solving this case is shown in Fig. 2. We are in effect using a 4-dimensional orthographic system in x, y, y', and f(y'); therefore the views shown in Fig. 2 represent the overlapping 3-dimensional spaces xy'f(y') and xyy'. Note that for the y'f(y') plane, y' is the independent variable, and the solutions of I_1 will be represented on this plane by the points at which the curve crosses the y' axis.

Since these solutions are valid for all values of x, they are lines of zero slope on the slope plane. The integral of a constant is a linear family of curves; therefore each solution of f(y') = 0 is a linear xy field. One such field is shown (Fig. 2).

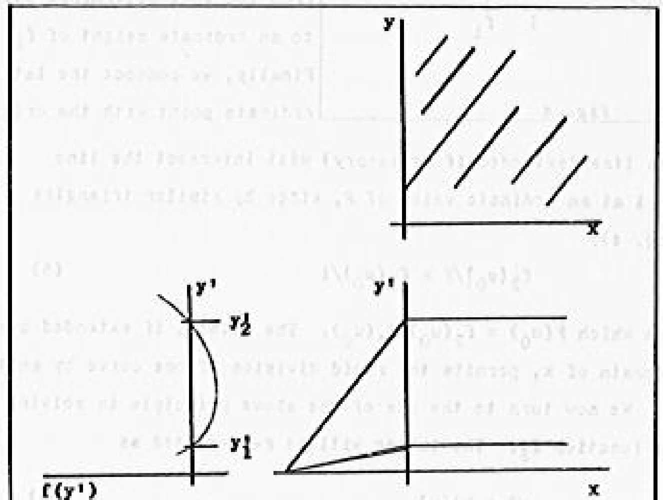


Fig. 2

Case 2

The function I_2 will ordinarily represent a single curve on the slope plane, and can be solved by simple integration to the solution plane. The form of the solution will be

$$y = \int y'dx + C \tag{4}$$

which implies a family of similar curves. Any known point (x_0, y_0) on the solution plane in effect selects the constant of integration; this results in a particular solution, such as the one shown in Fig. 3.

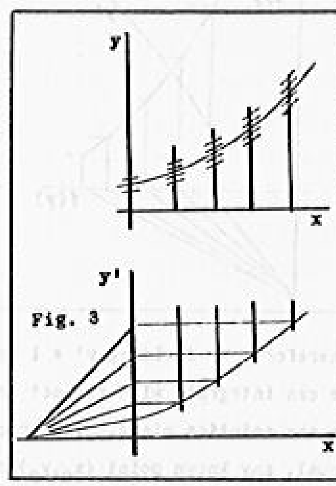


Fig. 3

Case 3

For this case we make use of the phase plane and some graphical arithmetic. Since we shall need to divide one ordinate by another, let us investigate how this can be done graphically. Assume that $F(u_0) = f_2(u_0)/f_1(u_0)$, where f_1 and f_2 represent functions of some variable u. In Fig. 4 the construction for determining P is shown.

From $f_1(u_0)$ we draw a horizontal line to the f(u) axis. Next we draw a line at 45 degrees to the latter axis and extend the line to the u axis. The value on the axis at the point of intersection is $f_1(u_0)$. Now we locate the point (f_1, f_2) by drawing a vertical line from the last determined point to an ordinate height of f_2. Finally, we connect the latter ordinate point with the origin.

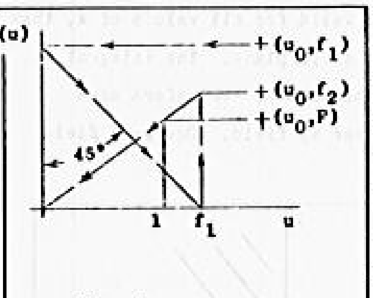


Fig. 4

This line (extended if necessary) will intersect the line x = 1 at an ordinate value of F, since by similar triangles (Fig. 4).

$$f_2(u_0)/F = f_1(u_0)/1 \qquad (5)$$

from which $F(u_0) = f_2(u_0)/f_1(u_0)$. The method, if extended over a domain of x, permits the rapid division of one curve by another.

We now turn to the use of the above principle in solving the function I_3. The latter will be represented as

$$y' = y'(y) \qquad (6)$$

on the phase plane. Now note that $1/y'$ is the same as dx/dy. If we plot (or construct) $1/y'$ as a function of y, we have

$$dx/dy = 1/y'(y) \qquad (7)$$

from which

$$x = \int (1/y')dy + C \qquad (8)$$

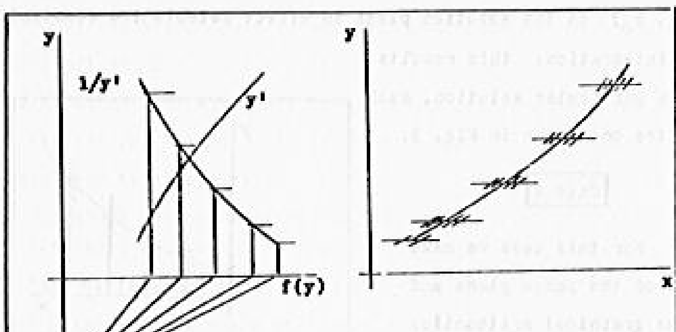


Fig. 5

Therefore, by dividing y' = 1 by y' = y'(y) on the phase plane, we can integrate with respect to y and obtain the correct field on the solution plane. The process is shown in Fig. 5. As usual, any known point (x_0, y_0) determines a particular solution.

Case 4

This is the general case, and is the only parametric solution for the field method in first order systems. The equation for I_4 is

$$f_4(y', x, y) = 0 \qquad (9)$$

and this can normally be expressed as

$$y' = y'(x, y) \qquad (10)$$

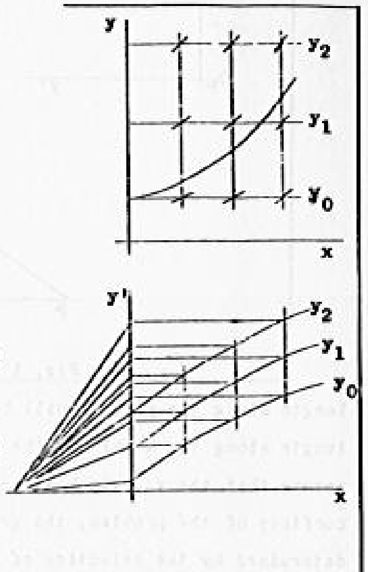


Fig. 6

If y is treated as a parameter, the frontal planes $y = y_0, y_1, y_2, \ldots, y_n$ appear as lines of zero slope on the solution plane. This is shown in Fig. 6. When one of these parametric y values is substituted into equation (10), there results the transformation

$$I_4 \rightarrow I_2 \qquad (11)$$

__for that value of y__. This I_2 curve may be plotted on the slope plane. Subsequent substitutions of different parametric values will produce other curves of the family on the slope plane.

When we begin the integration, each point on the slope plane represents the slope for a fixed value of __both__ x and y, and therefore produces only one slope line on the solution plane. Consequently, total integration of the slope plane curves ordinarily results in a distinct field on the solution plane, and not in multiple fields, as might be expected at first glance. Particular solutions are obtained in the usual fashion.

__Sample Problems__

We shall demonstrate the use of graphical methods with first order systems by turning to the fields of mathematics, heat transfer, and electronics. One simple example has been selected from each.

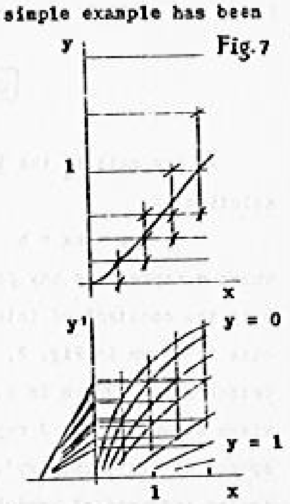


Fig. 7

Example 1. Plot the equation

$$xy + y = x^2 - y^3 \qquad (12)$$

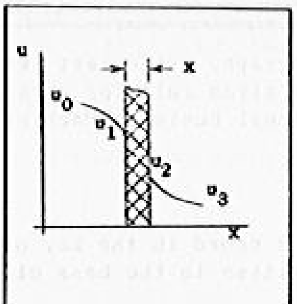
for $0 \leq x \leq 2$.

At best, equation (12) is awkward to plot by conventional means. However, if we differentiate implicitly with respect to x and solve for y' we get

$$y' = (2x - y)/(1 + x + 3y^2) \qquad (13)$$

which is a form of I_4. At x = 0, equation (12) shows that y is either zero or imaginary, and we assume that zero is the desired value. The solution has been carried out in Fig. 7. Here we see the y-parametric slope plane curves, the integration field on the solution plane, and the required curve.

Example 2. Given a temperature chart (Fig. 8) for heat flow through an insulating wall of thickness Δx, and the thermal conductivity k as a function of the temperature u. Using the given values of u_0, u_1, u_2, and u_3, determine the necessary thickness Δx for a prescribed allowable unit rate of heat loss q/A, where q is rate of heat flow and A is unit area, over the range $100 \leq q/A \leq 300$.



u_0	452
u_1	385
u_2	112
u_3	68

u	k
50	.092
100	.104
200	.116
300	.120
400	.123
500	.124
600	.125

Fig. 8

The differential equation representing steady state heat flow is

$$q\,dx = -kA\,du \qquad (14)$$

where q is expressed in BTU/hr, k is in BTU/hr/ft/deg., and A is in ft^2. Since k is a function of u and q is assumed to be constant, we have

$$(q/A)\,x = \int_{u_1}^{u_2} k\,du \qquad (15)$$

which is a form of I_2 and can be solved for the left hand side by simple integration of the right hand side. The quantity (q/A) x is parametric in q/A; by using a 4-dimensional system consisting of u, k, (q/A)Δx, and Δx, we can determine Δx for a prescribed value of q/A. The solution is shown in Fig. 9.

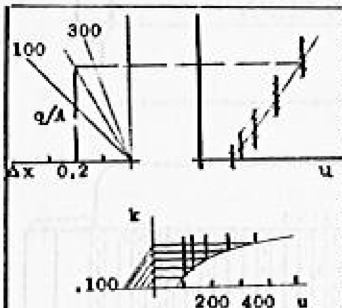


Fig. 9

Example 3. For the electronic circuit of Fig. 10, assume a resistive load, having a resistance r equal to the given function of the current i. If e is a function of time defined by e = 2t, determine the current in the circuit during the time interval $0 \leq t \leq 5$, where t is in seconds.

The instantaneous voltage-current relationship follows Ohm's law, and therefore is

$$e = ir \qquad (16)$$

where e is in volts, i is in amperes, and r is in ohms. By differentiating equation (16) with respect to time we get

$$\dot{e} = \dot{i}r + i\dot{r} \qquad (17)$$

From the given data, $\dot{e} = 2$. If we define r' to be dr/di, then $\dot{r} = r'\dot{i}$. Substituting these quantities into equation (17) and solving for $\dot{i}$ gives us

$$\dot{i} = 2/(ir' + r) \qquad (18)$$

Since this is I_3, we shall need to use the reciprocal of $\dot{i}$. Therefore the required equation is

$$1/\dot{i} = (ir' + r)/2 \qquad (19)$$

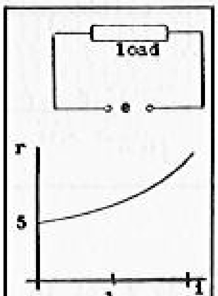


Fig. 10

The expression (ir' + r) can be obtained as a function of i by graphic construction. This is shown in Fig. 11. We obtain the division by 2 from a scaling of the ordinate axis in the right hand diagram. In Fig. 12 the last function of Fig. 11 has been replotted with the axes interchanged. By integrating with respect to i, we can determine the required function of t, and this is shown on the solution plane.

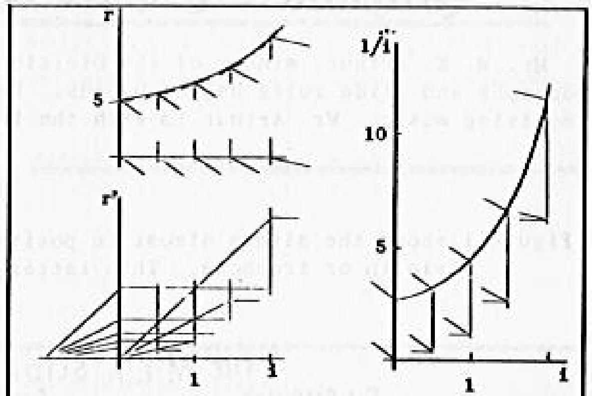


Fig. 11

Related Constructions

The graphical arithmetic of the last example (Fig. 11) may not be obvious to the uninitiated. Let us examine these operations more closely. Note that the differentiation is obtained by the simple process of constructing tangent lines to the r(i) curve, and then drawing these slope lines from the pole to the r' axis. From the various points of intersection with this axis,

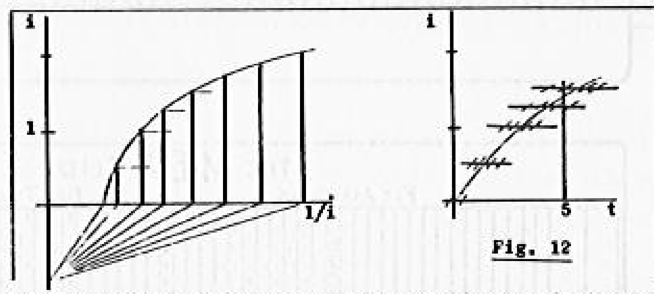


Fig. 12

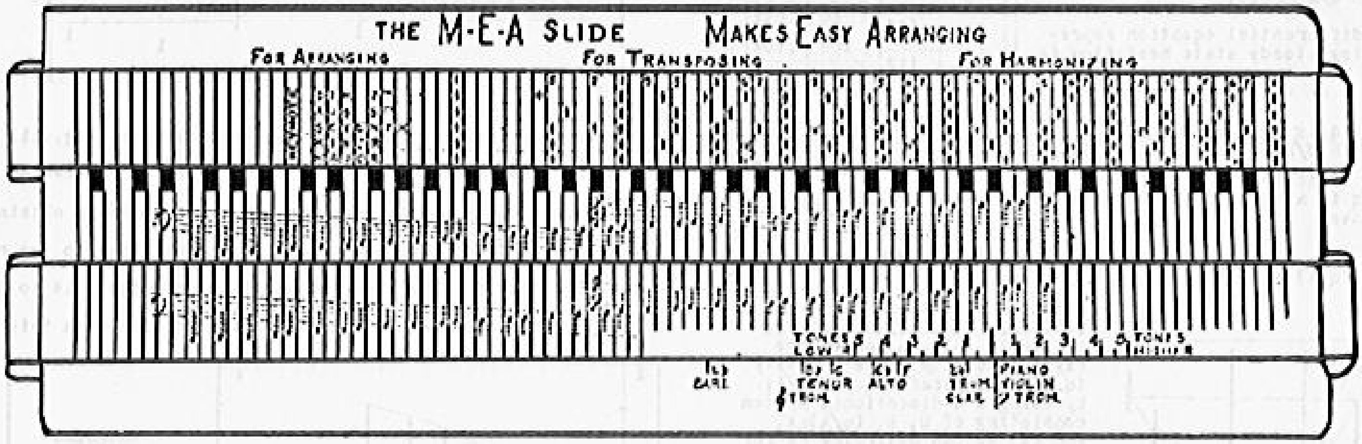
horizontal lines are drawn to the appropriate ordinate, locating points on the curve of slopes, or <u>derived</u> curve. The curve itself need not be drawn, as the slope values are to be multiplied by corresponding values of i. Now if lines are drawn from the origin through the intersection of i = 1 and each of the preceding horizontal lines, and if these lines are then extended to the ordinates which the horizontal lines extend to, the new ordinates will be the product ir'. These ordinates have been projected to their corresponding positions on the summation plane at the right, and the r values have been added by parallel construction. The final curve will be proportional to (ir' + r). If the ordinate axis on the summation plane is calibrated such that the unit distance is double that on the r and r' axes, the effect is the division of the function by 2, and this is in agreement with equation (19).

Finally, it may be necessary to compensate for any error introduced in constructing the slopes to the r(i) curve. The accuracy can be checked by multiplying r(i) by i(t). Results of this multiplication should be e(t), or 2t. If the error is appreciable, a correction should be applied. All such operations are easily performed graphically.

Graphics In Music

Mr. M. E. Arthur, winner of the Division's Nomography prize last year says that the use of nomographs and slide rules has no bounds. Here is a slide rule for arranging, transposing and harmonizing music. Mr. Arthur is with the International Business Machines Corp. in Oswego, N.Y.

Figure 1 shows the slides almost in position for a chord in the key of C for piano, violin or trombone. This latter when written in the bass clef only.



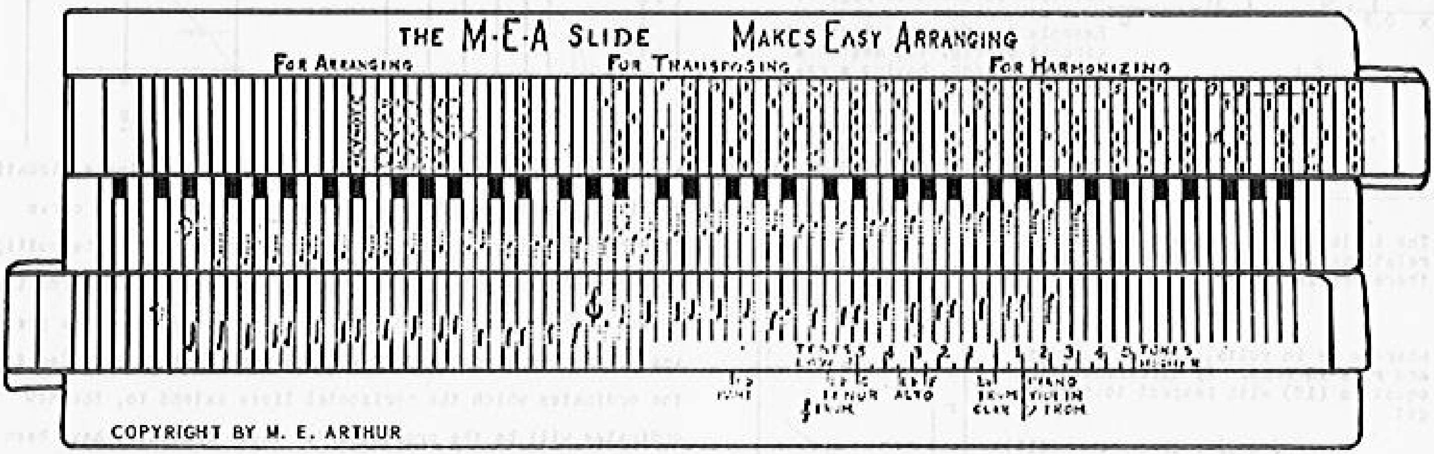


Figure 2 shows slide 1 set for a chord in E♭ and slide 2 set to transpose for B♭ trumpet, or clarinet, when the music is to remain in the original key. This same setting of slide 2 might also be used to transpose one tone higher for piano, violin, etc., or to transpose 2½ tones lower for horns in F or 3½ tones lower for E♭ alto saxophone.

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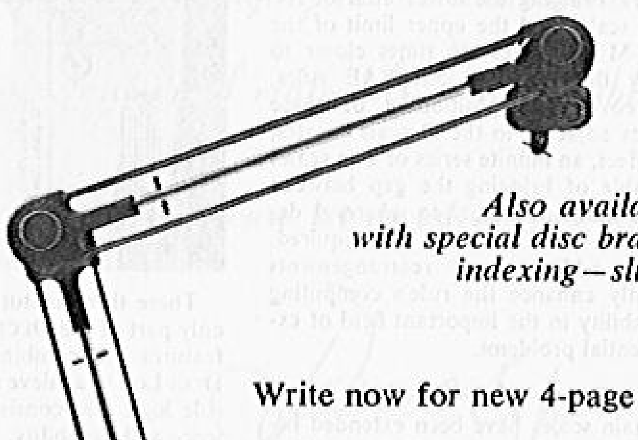

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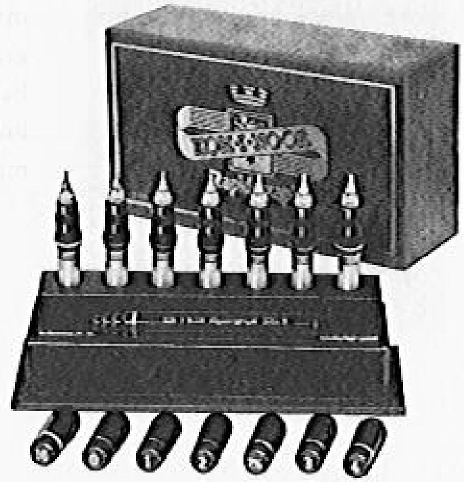

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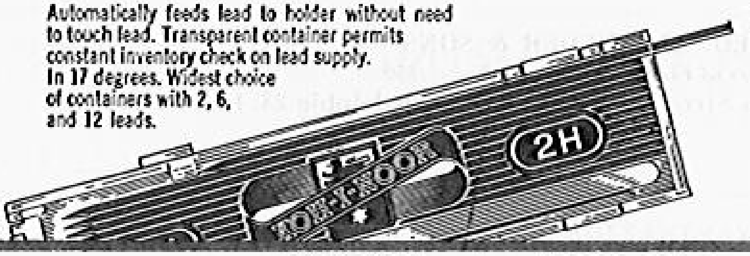

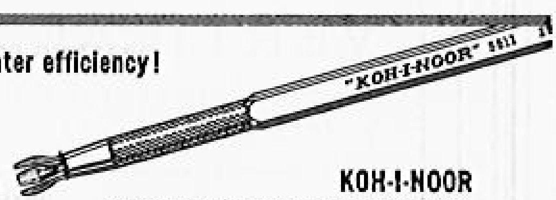

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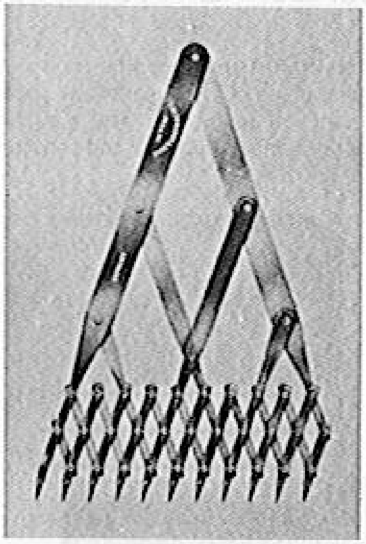

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By Irwin Wladaver, New York University

There is nothing like self-deception to make a man feel he amounts to something. And self-deception is the surest road to self-destruction.

What do I mean? I mean that we can hide the truth from others for a while and thereby live a little longer in our accustomed style. But if we hide the truth from ourselves and thereby come to think we can live prosperously indefinitely in our own make-believe world, what an awakening there will be!

Let's face a few facts: During the past few years more and more often we began to hear the words "analysis and synthesis." We didn't know exactly what the words meant or should have meant to us, but somehow they were comforting - when they weren't annoying. Somehow we felt that if we could only latch on to "analysis and synthesis," through some process of absorption we would soon be respectable once more and people would let us alone. And so we did what they were doing in other departments. We talked analysis and synthesis. We neither analyzed nor synthesized. Nothing happened. How could it?

Our continuing frustration taught us precious little. The strongest possible deputation of Divisional leaders visited the then reigning monarchs of ASEE. The ASEE chiefs were impressed with the obvious importance of our work in the education of young engineers and they said so. A very pleasant visit. Any effect? Of course not. Very soon after, we found that something had happened in the interim; our work was not important any longer in the education of young engineers.

Then we started to make some deals. Oh, they didn't look like deals: we claimed that our courses were now upgraded, unquote, with the addition of graphical computation and with the subtraction of a variety of topics from auxiliaries to screw threads; with an emphasis on picture drawing and a de-emphasis of dimensioning. We talked widely of graphical communications. The greatest upgrading of all came in the form of a name change to engineering graphics and now we were able to conceal the details under a veil of generality and integration. What a way to hide descriptive geometry, the most valuable tool for analysis and synthesis (there I go again) in the entire crib!

I believe our colleagues, the curriculum makers, may be operating under a temporary illusion that what we are doing now is better than what we used to do. Far worse it is that some of us believe it.

The truth is that graphic statics was discarded years ago. The truth is that the definitive book on nomography is due to d'Ocagne. When? 1899 The truth is that graphical and mechanical computation has never, I think, been more fully nor more rigorously presented than by Lipka. When? 1918.

I don't imply that antiquity disqualifies a subject. But these subjects had been fading away. Today they are far less critical than what we have discarded. Even so, I do assert that to present empirical equations, nomography, graphical integration and differentiation in a single short semester so that they will have some lasting meaning to a student is to present arrant nonsense. But to offer these topics in graphical computation together with engineering drawing freehand or instrumental, together with the essential elements of descriptive geometry and God knows what all else, is to build an edifice without a foundation. How long can it stand? It will inevitably crumble and perish. And it will destroy those who built it with heterogeneity and no mortar.

Do you know the latest fashion? It's design. Let's save our courses with design. Does this make sense? Yes, I think it does. But how in the world is a student going to design if he can't draw? I believe he won't be able to analyze or synthesize or even communicate!

Are there any remedies? There must be: we have a crew of self appointed but dedicated and competent physicians who have high hopes of making a complete diagnosis. They are hard at work; if solutions can be found, these people may be the ones to find the proper remedies and dosages. Yet I can't help wondering about the futility of trying to cure a patient who won't admit he's sick.

This is why I say it's tempting and opportunistic and maybe temporarily useful to deceive the other fellow. But let's not fool ourselves into believing our house is in order. It isn't.

Letters-to-the-Editor

UNIVERSITY OF ILLINOIS
NAVY PIER
CHICAGO 8, ILLINOIS

Professor Mary F. Blade
Cooper Union
Cooper Square
New York 8, New York

March 16, 1962

Dear Professor Mary Blade:

In answer to your suggestion that I write an article, either agreeing or disagreeing with John H. Fernandes, my answer would be "NO." I am saying this for two reasons. First, I do not know Professor Fernandes. I have never met him personally, and would not like to make any deregatory remarks without meeting him personally. Also, I may say some things in an article of this type that may cause some of my very good friends in the drawing division to feel differently towards me, and since I am getting close to retirement, I would not care to lose any of my close friends in the division.

However, I have read the article over very thoroughly, underlining many items with a red pencil, giving many comments along the margins and on the page in between columns. I will list some of these comments and you may use them in any way you wish.

First, I would like to state that Mr. Fernandes has written an article which may help to straighten out some of the people that he suggests have shown a degree of mental stagnation. Since I am not in any way effected by this situation in my department, I was rather surprised to hear this statement, as I feel a situation of this kind is pretty much the responsibility of the person who heads the department or college in which the stagnant person is employed.

Starting from the beginning of this article, I may state that I am very much interested in his statement of a merger of departments and I will comment more on that as I go along. I will agree with him that possibly the lack of sufficient time causes many of the people in graphics to fail to work more along the research field than they do and I do agree with him that reduction of load would be one way of taking care of this situation. To some extent, I may agree with him that many of the Professors in Graphics are too colloquial and their horizons become too narrow. That probably stems from the fact that many of the graphics teachers have specialized in graphics in college rather than some other phase of the engineering field.

Beginning with his sentence "Graphics is a necessary and important basic engineering science" and continuing on "faculties have a tendency to over-specialize their own area and try to empire build" is not only typical of the graphics division but all departments in the college of engineering. I agree with him thoroughly that the graphics faculty are a dedicated lot which is indicated by the fine attendance at our mid-year and annual meetings. I will also agree with him that a misfit or a poor teacher isn't going to do any better in the graphics department than in any other department.

I am not too happy over his statement of "glorified high school teachers." I myself was one of those so-called glorified high school teachers for 25 years and am proud of it. It was not until many years after I started teaching that I discovered how little I knew about teaching. I have come to the conclusion that many of the G.H.S.T. are superior as teachers to over 75% of the college teachers who have had no previous teacher training before entering the college teaching profession.

Mr. Fernandes' statement in the next paragraph, "First, I believe a college owes a young freshman and sophomore some of its best teachers," I agree with him 100%. I feel a young freshman engineer in his formative years in college needs the very best advisors in the engineering field that we are able to give him. In our department, we have a larger percentage of our people acting as advisors for freshmen than any other department in the college. I believe this to be an indication of the appreciation our Dean of Engineering has for the type of men we have in our department.

In many cases, a person teaching in college is doing so because he is unable to hold his own in industry. This is also very serious an indictment against the make-up of many of our college of engineering departments. I do not feel that this is typical of very many of the departments in graphics as most of these men are able to leave the field of teaching and go into engineering offices and better themselves financially.

In Professor Fernandes' next paragraph "The solution I am trying to incorporate ------------------------", I believe is an excellent idea and I hope that he will be able to carry it through to completion. When he refers to this being a "chore", I believe he is referring to the type of individual that I spoke of above who is unable to hold his own in industry and does not belong on a teaching staff in the college of engineering. This type of individual is strictly an engineering scientist who has never had any experience in the engineering field. There is no doubt that his suggestion that he place a person with real enthusiasm for graphics and its development as a permanent Professor of the graphics division is very good. His developing of this situation in that paragraph is excellent.

The end of the paragraph in the middle of page 21 on the left starting with "The end result is ------------------" is probably the crux of our whole problem in graphics at the present time and his statement of increasing the students' understanding of the basic concepts of the graphics strikes a very vital point in our future development.

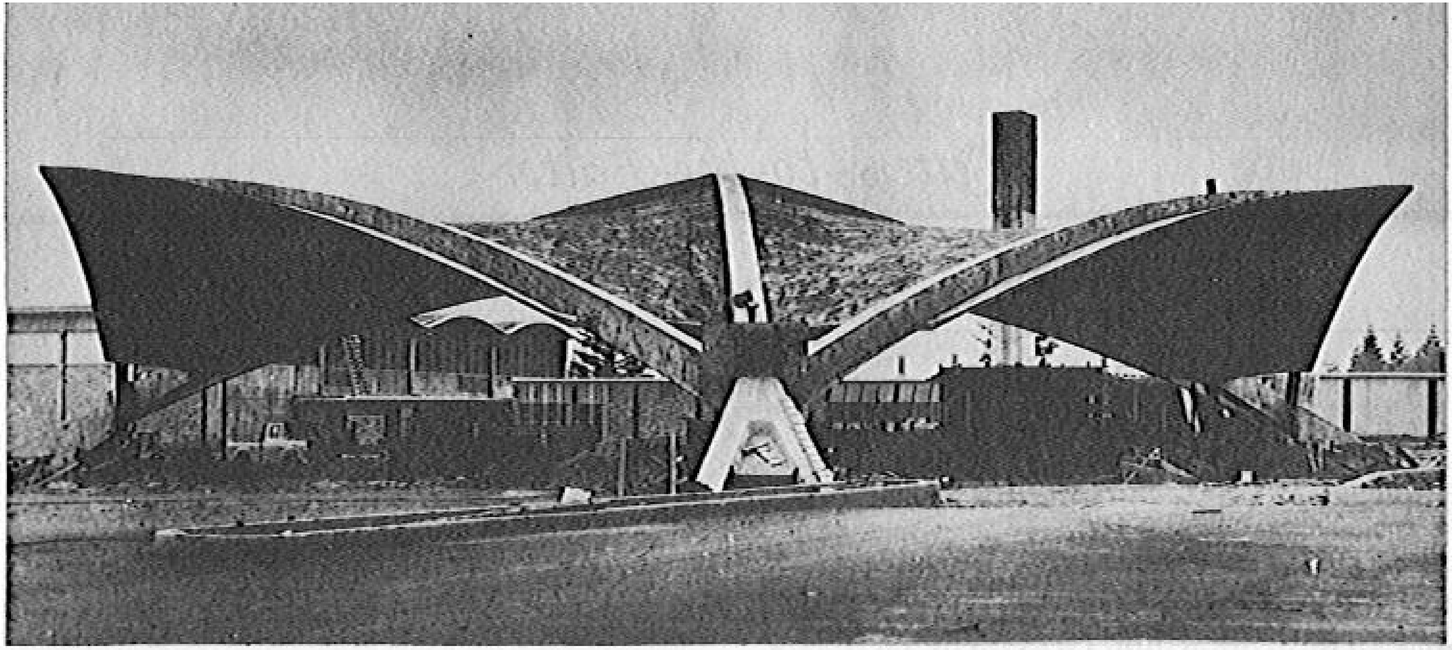
He goes on in the next paragraph and talks about the combination of graphics with one of the professional engineering departments. I believe this has merit where there is no department/curriculum of General Engineering as we are fortunate in having at the University of Illinois. I also believe that if graphics is to be combined with another department as Mr. Fernandes implies, it should be with the mechanical engineering department. I am sure that this department can do an efficient job in handling the subject of graphics.

He compares the work of the graphics department with the English Department. This comparison ends with the statement that graphics is the language of the engineer. The comparison between the two does not hold in relation to work taken in high school. Most high schools will require three to four years of english while very few require work in graphics. As a matter of fact, it is getting to the point that a student is very fortunate if he is able to get one semester of drawing in high school before entering college. I can state from personal experiences that the average high school student is not mature enough to grasp the theory of graphics.

In Mr. Fernandes' final summation, I feel that he is very sound in his proposal for a syllabus for the graphics program and his suggestion that the honors program may help to give opportunities to the superior students to obtain advanced work,has a great deal of merit. I agree that he truly has a challenge before him and I wish him all the success possible.

Very truly yours,

C. I. Carlson
Professor and Head
General Engineering Dept.



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