ENGINEERING DESIGN GRAPHICS JOURNAL

SPRING 1979 VOLUME 43 NUMBER 2

ENGINEERING DESIGN GRAPHICS JOURNAL

CALENDAR

ASEE ANNUAL CONFERENCES

1979 - Louisiana State University, Baton Rouge. June 25 - 28

1980 - University of Massachusetts, Amherst. June 22 - 27

1981 - University of Southern California

EDGD MIDYEAR CONFERENCES

1980-Cogswell College

1981-North Carolina State

ENGINEERING DESIGN GRAPHICS JOURNAL is published - one volume per year, three numbers per volume, in Winter, Spring, and Fall - by the Engineering Design Graphics Division of the American Society for Engineering Education, for teachers and industrial practioners of Engineering Graphics, Computer Graphics, and Design Graphics, and Creative Design.

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ENGINEERING DESIGN GRAPHICS JOURNAL OBJECTIVES:
The objectives of the JOURNAL are:
1. To publish articles of interest to teachers and practioners of Engineering Graphics, Computer Graphics and subjects allied to fundamentals of engineering.
2. To stimulate the preparation of articles and papers on topics of interest to its membership.
3. To encourage teachers of Graphics to innovate on, experiment with, and test appropriate techniques and topics to further improve quality of and modernize instruction and courses.
4. To encourage research, development, and refinement of theory and applications of engineering graphics for understanding and practice.

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1. All copy is to be typed, double-spaced, on one side only, on white paper, using a black ribbon.

2. All pages of the manuscript are to be consecutively numbered.

3. Two copies of each manuscript are required.

4. Refer to all graphs, diagrams, photographs, or illustrations in your text as Figure 1, Figure 2, etc. Be sure to identify all such material accordingly, either on the front or back of each.
Illustrations cannot be redrawn; they are reproduced directly from submitted material and will be reduced to fit the columnar page.

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5. Submit a recent photograph (head to chest) showing your natural pose. Make sure your name and address is on the reverse side.

6. Please make all changes in your manuscript prior to submitting it. Check carefully spelling, structure, and clarity to avoid ambiguity and maximize continuity of thought. Proofreading will be done by the editorial staff. Galley proofs cannot be submitted to authors for review.

7. Enclose all material unfolded in large size envelope. Use heavy cardboard to prevent bending.

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9. Send all material, in one mailing to:
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All articles submitted will be reviewed by several authorities in the field associated with the content of each paper before acceptance. Current newsworthy items will not be reviewed in this manner, but will be accepted at the discretion of the editors.

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The following deadlines for the submission of articles, announcements, or advertising for the three issues of the JOURNAL:
Fall--September 15
Winter--December 1
Spring--February 15

THE AMERICAN SOCIETY FOR ENGINEERING EDUCATION

Engineering Design Graphics Journal

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ELECTION RESULTS

As usual, the Nominating committee presented last Fall a slate of officers which guaranteed that the Division would be the real winner regardless of the outcome of the election.

That outcome has been announced by Chairman Kearns, and the new officers are: Mary Jasper, Director of Publications; Charles Keith, Secretary/Treasurer, and Paul DeJong, Vice Chairman.

Those newly-elected officers will take office in June and join the Board under the able leadership of incoming Chairman Leon Billow.

To those new officers, the Division extends its best wishes for a productive and constructive term of office. Perhaps even more important, the Division owes - and extends - a large debt of thanks to those who also ran; they have contributed tremendously in the past and will surely continue to play important roles in keeping the Division a strong and viable group. Bob Foster, Frank Croft, John Kreifeldt -- our hat is off to you!

Clyde H. Kearns
Chairman, EDGD

Cover: Scenes from the campus of Louisiana State University, provided by Clarence E. Hall. Thanks, Clarence!

CONTENTS

EDITORIAL

This is the last regular issue of the JOURNAL that we will have the task - and privilege - of producing. That sentence requires a little clarification.

First, while it is the last "regular" issue, there still remains the upcoming INDEX issue, which - we hope - will precede the Annual conference. A lot of assembly remains to be done.

Second, I said "we" and must - even if it smacks of nepotism - recognize that if it weren't for my dear wife Judy, none of this would have ever been finished. She hammers out articles and letters at the most unlikely hours, and has to put up with some pretty awful editorial notes and dictation. On top of that she works for peanuts. Many who attend conferences know my "better half", Judy, - she's also quite a character - and I'm sure you'll join me in thanking her for her help, patience, and support.

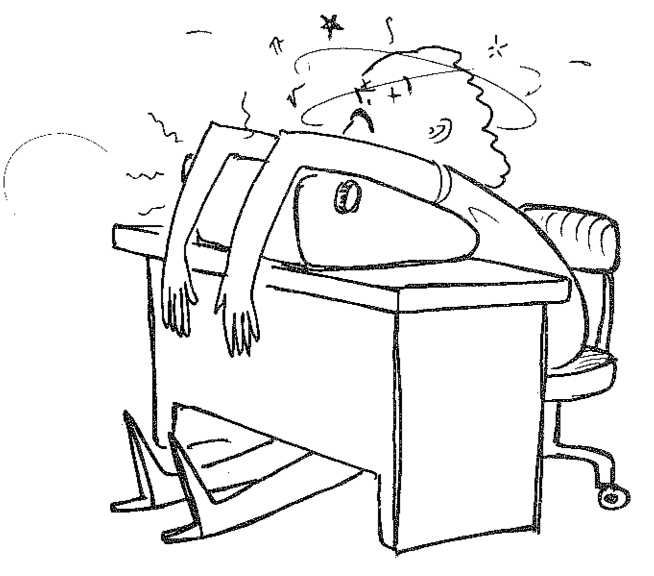
It would be at least criminal to fail to recognize and thank Ed O'Niell and the Kendall/Hunt Publishing Company people for their work and generousity. They are great people to work with, and Ed can't do enough to make the Journal a success...and they sure have to "fill in a lot of blanks" working with us amateurs. Ed, I hope you will accept my sincere thanks and extend them to everyone there who contributed so much.

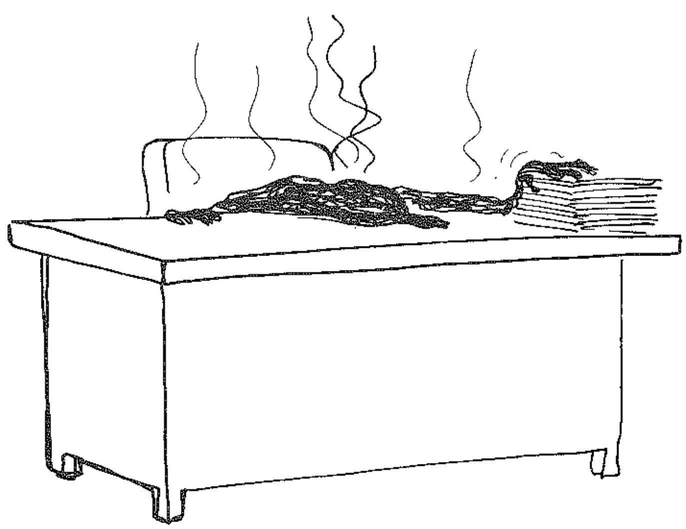
Last, while the JOURNAL is a <u>huge</u> task, it is an unparalleled experience that we wouldn't give up for anything. Working with all the authors, reviewers, Directors, editors and readers has been more enjoyable and broadening than I can describe. I have said before and believe even more firmly that EDGD is made up of the finest people in the world.

Looking back, a good many things we did - going to Metric format, for instance, but I wish we had been able to accomplish more. There are many things unfinished - even unstarted - that would be positive and constructive for the Division. There's a message in that for us all, I believe; and that message is do what you can, contribute what you can, but that nothing will ever be done if you don't <u>start</u>.

The JOURNAL is healthy. Articles continue to come in and the new Editor will have material to work with, which is important. I wish that person all the best, and take this opportunity to pass on the statement that Jim Earle gave me three years ago -- " You only have nine more issues to go ", which says it all pretty well.

Thanks to you all for your confidence and help.





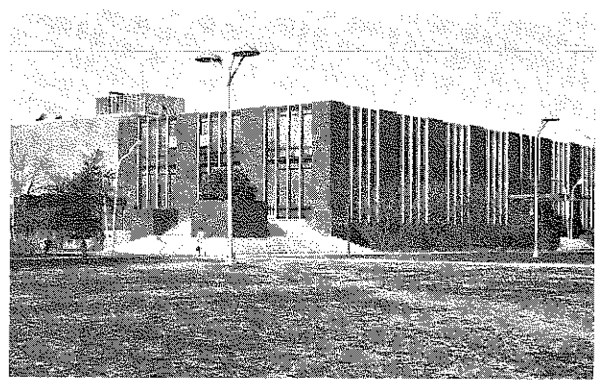
MIDYEAR CONFERENCE HIGHLIGHTS
MISSISSIPPI STATE UNIVERSITY

When the Mid-Year Meeting is scheduled to be held in the "Sun Belt", we "Snow Birds" in the north flock down to escape the bitter temperatures and bask in the sunshine. SURPISE!!! This year Mother Nature dealt a cruel blow to us and gave the southeast and Starkville, Mississippi, in particular, a cold blast of arctic air that sent the temperatures down to near zero and made many of us feel as though we had never left home.

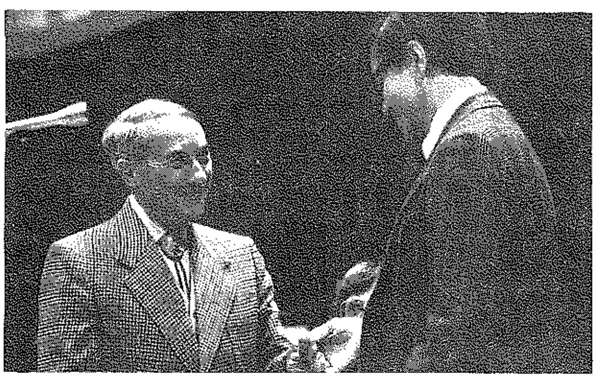
Without regard to the very cold weather, the meeting was both entertaining and informative. Sessions on Cartography, Computer Graphics, and Metrication highlighted the meeting. A rousing session about the need for graphics in upper level engineering courses stimulated much discussion in the meeting and in the social gatherings. Informative tours of The Herschede Hall Clock Company and Gulf States Manufacturing Company were available to Conferees and their spouses. Persons who toured the Herschede Hall Clock Company discovered that clocks were not the only product manufactured there. Herschede also produces an electric trowling motor for fisherman.

A highlight review would be incomplete without expressing the appreciation of the Division to Mary Jasper who developed and coordinated the program. In Vancouver, Mary struck up the battle cry "Y'ALL COME". For those of us who came, we were not disappointed. The Division recognizes Hunter Eubanks and all the staff of the Engineering Graphics Department of MSU for being such gracious hosts. We thank you and look forward to your hospitality in the future.

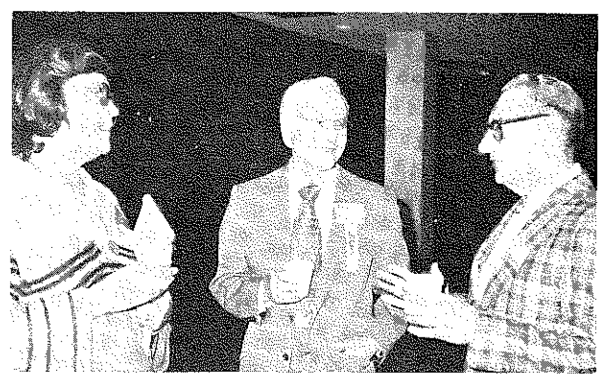
Mid-Year Meeting Social Hour



Student Union Building at MSU



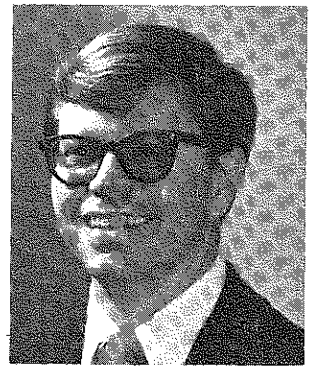
Frank Oppenheimer Presenting the Oppenheimer Award to John Demel



Mary Jasper, Wilbur Pearson, and Leon Billow discuss the day's events

from the midyear conference...

COMPUTER USE IN FRESHMAN DESIGN PROJECTS AT TEXAS A & M UNIVERSITY



John T. Demel
Texas A & M

Alan D. Kent
Texas A & M

William H. Zaggle
Texas A & M

Oppenheimer Award

ABSTRACT

This paper presents the overall plan to use computer-aided desing and computer graphics in the freshman design project. Progress in software development and equipment evaluation is covered in some detail. Costs for data processing and proposed equipment are also discussed.

INTRODUCTION

During the past three years the Engineering Design Graphics (EDG) staff members at Texas A&M University (TAMU) have visited a variety of industries. These industries include aircraft, petroleum, heavy manufacturing, and electronics. All of these have either computer graphics or computer-aided design (CAD) in some form. The ultimate system is produced by National Computer Systems of Minneapolis which goes from design to product without a drawing. With the cost of computer hardware decreasing, the capabilities for computer-aided design and computer graphics is now in reach of smaller industries and engineering firms. These trips to industry and their results inspired the staff to consider introducing CAD and computer graphics into the freshman engineering design graphics courses. The problem was to determine how they might best be used. The program for teaching the students the basics in graphics and descriptive geometry are well established at TAMU.

Therefore, it was decided that the design portion of the graphics courses was to be used as the vehicle for demonstration and use. A proposal was submitted to the national Science Foundation's Local Course Improvement (LOCI) program to support the development of such a design package. The award to TAMU was made in May 1978. This paper discusses the overall plan, the progress thus far, the equipment selection, and the computing costs.

THE PLAN

Engineering students at TAMU take two two-credit Engineering Design Graphics courses. In each of these they participate in a design project. The goal for the EDG computer-aided design package is to show the advantages of CAD and computer graphics by having the students use them in the design process. The students are to be <u>users</u> for this package not programmers. They do some programming in their Introduction to Engineering courses offered by the various engineering departments, but the level is not such that they can do the sophisticated programming required for computer graphics and finish their design project within the time required.

The package was to be developed in both FORTRAN and BASIC languages and to include a sketching routine and a standard fastener library as part of the design work. Investigations have shown that almost all computers which support FORTRAN will support BASIC and it is now the intention to do the development in BASIC so that even microcomputers can use the package.

When visiting industry, the EDG staff found that the design process had not changed but productivity could be increased simply by using the computer-based aids to design and analysis. Thus the package is being developed around the design sequence that is currently used in the freshman design project. This design sequence consists of six stages: Problem Identification, Preliminary Ideas, Refinement, Analysis, Decision, and Implementation. The computer can be used in each of these stages but not for all processes in each stage. The package will have some software for each stage of the design process rather then just the two areas mentioned in the previous paragraph. Some details on the package are provided in the next section.

In industry, the design is generally kept in a central computer with the contributions and modifications made to that central design data bank by the designers. The student design projects, a product design, will be set up in a similar manner. They will keep their designs on some storage medium (disks, floppy disks, or tapes) and then make changes and modifications to their design and store the new information on their disk.

PROGRESS

Spring and Summer 1978 - the computer equipment available prior to the contract award was the TAMU Data Processing Center's (DPC) computer and it's peripherals. This computer is an Amdahl 470-V6 that uses an IBM 370 operating system which supports various levels of FORTRAN, APL, TSO (for graphics), and WYLBUR (an interactive text-editing and batch program submittal system). An off-line drum plotter is also available. In the spring of 1978 some of the students in the EDG 408, Computer Graphics, used WYLBUR to write programs in FORTRAN with the output being generated either on a printer-plotter or a drum-plotter.

During the first summer session, a Tektronix graphics terminal was obtained from the DPC for the cost of the terminal maintenance. At the same time, a student was hired to develop software and learn how much TSO could do in the development of a software package and how expensive it was to use. The first software written was a program to help the students use WYLBUR. The program, called LITTLE WILLIE, was tested during the second summer session by the computer graphics students. A discussion of the experience with LITTLE WILLIE is located in the Student and Staff Response section.

Fall 1978 - For the fall semester the goals were to develop the overall plan in more detail and use WYLBUR and the Tektronix terminal to determine what they were capable of and what sort of costs could be anticipated. As was stated earlier, the design process had not changed. Thus, a program was written that would be a monitor for the creation and use of interactive files on WYLBUR. This program is called CREATOR and is shown in Figure 1.

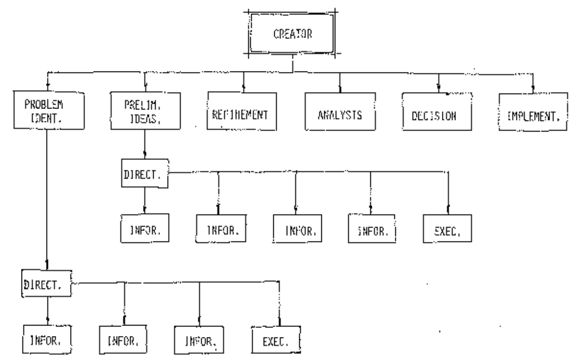


Figure 1. The CREATOR Package

There will be two types of files. Although both will be interactive to a certain extent, some will merely ask questions as to what topic the user wishes to see and then display the information requested. These will allow him to store on his media the portion that he needs and then returns him to the main file for his next step. Figure 2 shows the organization for Problem Identification. In this case, population data and other similar data will be stored

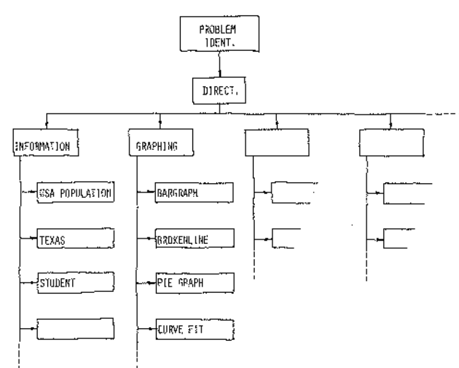


Figure 2. The Problem Identification Stage

in the moderately interactive or information files. The interactive file that draws graphs will be heavily interactive and each step calls for the user to answer a question and then the results of that answer are displayed. An example is shown in Figures 3 and 4. This is typical of part of the questions that are asked. Those that have already been asked and which created Figure 3 are responses to: What type of graph do you wish to draw?, How wide is your graph?, How high is your graph?. A more complete discussion of the experiences with the software written thus far is in the Student and Staff Response section.

The next step is the Preliminary Ideas stage shown in Figure 5. Here, brainstorming is done first to establish the many possibilities for solutions. Although the computer might be used for this activity, it is planned that this will be done by the groups of students without the aid of the computer. Once brainstorming is finished, the students can store their ideas on either disks or tapes. The files that have been developed for Preliminary Ideas are GINPLOT and GINPLOTZ. Two-dimensional sketching can be accessed through the GINPLOT program as shown in Figures 6 and 7. GINPLOT can draw lines, points, circles, polygons, rectangles, and put text anywhere desired on the screen. Figure 7 shows an oblique drawing and the X-Y coordinates used to display that figure. GINPLOTZ will provide orthographic drawings and pictorials, but at this time has not been tested and will be reported in a future paper. GINPLOT was originally written for the Amdahl, but was rewritten in BASIC when a microcomputer was loaned to the department for a week. Circles on WYLBUR were very difficult to program and the examples shown were generated with the microcomputer.

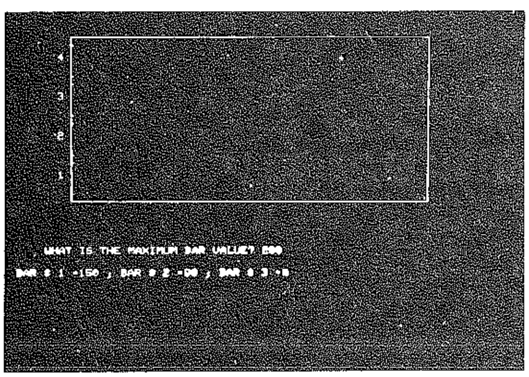


Figure 3. Bar Graph Example I

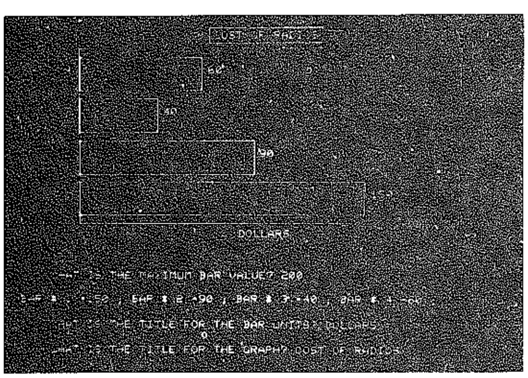


Figure 4. Bar Graph Example II

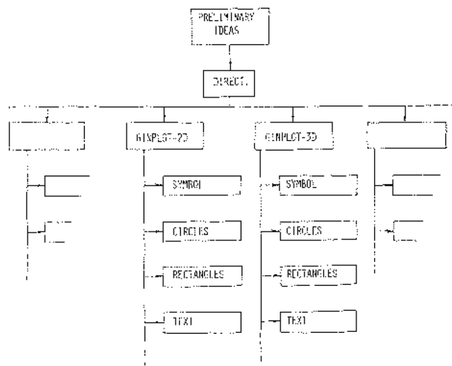


Figure 5. The Preliminary Ideas Stage

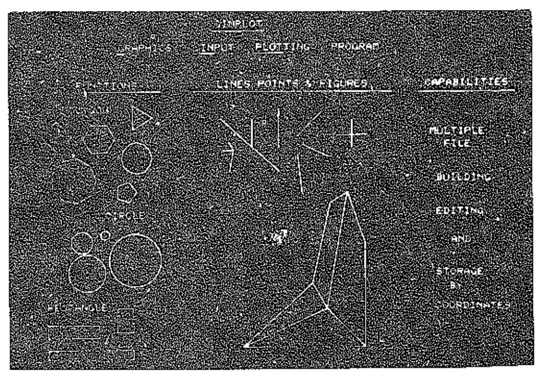


Figure 6. GINPLOT Example-Functions

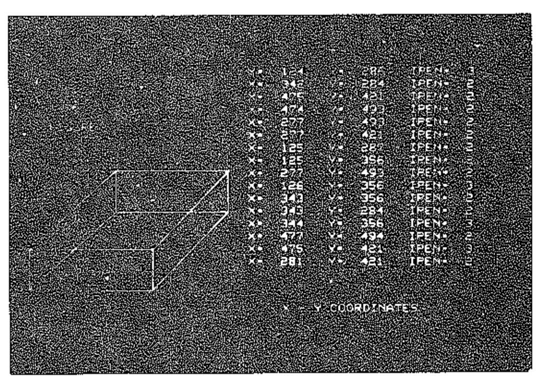


Figure 7. GINPLOT Example-Figure and Coordinates

The Refinement stage, shown in Figure 8, is a process that takes the sketches developed in the Preliminary Ideas stage and initiates scale drawings of the products to be developed. To do this, the student must be able to retrieve the sketches that he drew during the Preliminary Ideas stage and modify those to become scale drawings. This means that to be successful and efficient he must have access to standard thicknesses of materials and standard fastener sizes and types. Thus, Refinement is a combination of GINPLOTZ with additional capabilities and information on standard parts and materials.

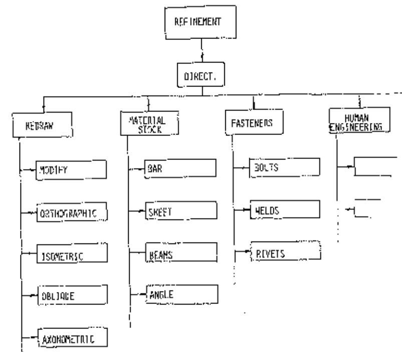


Figure 8. The Refinement Stage

The rest of the design process is yet to be developed. The Analysis stage will allow the student to have limited kinematic linkage and strength of materials analysis capabilities. Since cost is an important design factor, the Analysis files will contain this data and will be created so that they can be updated as needed and utilized in the Decision stage of the design process. The implementation stage, for the TAMU students, consists of developing a set of working drawings of their product. Whether the CREATOR package will be capable of doing things like dimensioning and building a parts list will depend on the hardware available. Programs can be written to do this, yet it remains a question of whether a small computer can efficiently handle the software required.

STUDENT AND FACULTY RESPONSE

Some of the computer graphics students found WYLBUR easy to use, but others had problems because they could not visualize the interaction within the system. In order to make WYLBUR less complicated for the students, LITTLE WILLIE was written. It was designed so that the students could sign on the computer the proper commands.

This program worked very well for the students who had not used WYLBUR before. However, it was written so that the student had to wait for some information to be printed out before he could answer the questions which prompted the computer to do the next operation. They became impatient with LITTLE WILLIE and eventually learned to use WYLBUR. This experience showed that the interactive programs were valuable but must be written with the user in mind and must be tested constantly to get the users reactions. Frequent users of interactive programs beomce familiar with the sequence of operations. The software must anticipate this and give the user the option of reading or rejecting explanatory material.

Prior to the beginning of the fall semester 1978, a presentation was made to the TAMU EDG faculty. This was done to provide some continuing education and to keep them up to date on the progress of the project. Two activities were planned. The first was a printer-plot graphing routine that would allow an infinite variety of bar graphs to be created on the alphanumeric CRTs. The second was to have the staff use LITTLE WILLIE to write a program. The staff members were organized in teams of twos with one staff member who had done some programming and one who had very little or no programming experience. Although there were some minor problems, most of the staff members understood the rudiments of how the system worked and appreciated the interactivity of the system. The understanding was due to the use of graphical aids to explain the system and what different commands did. These faculty demonstrations will be continued at appropriate times so that when the final package is ready the staff will be ready to use it with a minimum amount of transition time.

After GINPLOT was written, two EDG classes were given the opportunity to work at the terminal and generate pictures. The first group was the Industrial Freehand Sketching class of which none of the students had any previous computer or computer graphics experience. The second group was the Computer Graphics class consisting of a cross of engineering, computer science, and engineering graphic option students, most of which had limited computer experience but little, if any, computer graphics experience. To familiarize the students in both classes with the GINPLOT routine, handouts were distributed for reference, followed by a short verbal explanation and a brief visual demonstration to illustrate GINPLOT and it's computer graphics capabilities.

For the Industrial Sketching students to be given this type of opportunity brought about mixed emotions in the class; some were apprehensive while others were ecstatic. After the demonstration, three or four students each class period were to use the system. Most of the students were afraid of the system and terminal fearing that they might break something if they pushed the wrong button. When mistakes were made by the student, the system was set up to "beep" at the user prompting a new command to continue the program. Through the use of the "beep" and reassurance from the instructor, the initial fears of the students diminished and they successfully created pictures on the CRT and recalled and modified their pictures. All the students enjoyed working with GINPLOT and could see its possibilities in the area of sketching but would have like to spend more time on the system.

The Computer Graphics class had prior experience using WYLBUR to write and submit batch programs. These students found that GINPLOT gave them a powerful, flexible tool to create drawings and that it was easy to use. They also thought that using the terminal was enjoyable and most of the students looked forward to the new developments for GINPLOT. Although these students did not complain about the computer response time for drawing and replotting, they had not had the opportunity to work at communications rates higher than 300 baud. The few staff members who used the microcomputer-supported terminal to draw pictures with GINPLOT at 9600 baud subsequently found the WYLBUR-supported terminal to be very slow.

The graphical aids used for the EDG staff orientation also worked well to explain WYLBUR to the students in computer graphics during the fall semester. Additional graphical aids were developed to explain the operation of GINPLOT to the students in Industrial Freehand Sketching and Computer Graphics. Examples of the type of graphics used to explain WYLBUR are shown in Figures 9 and 10. These were originally developed as a series of five overlays but are shown here as composite drawings. Figure 9 explains that the WYLBUR user sits at a desk (active file) and he has at his disposal the computer and a filing system in which to store his programs. If he uses the correct series of commands, he can write a program, make a copy of the program and store it in his file, submit the program to the computer for processing and retrieve the output. He also has the options at any point of getting rid of the copy on his desk, removing all file copies, and throwing away the copy of the program that has been submitted for processing.

Figure 10 shows a little man that will jump out of the files and help the computer user. Rather than using computer commands, the little man asks the user a series of questions about what the user is trying to do. When the user answers the little man, he then translates the answers into the commands that the computer must have to function. The little man can be thought of as LITTLE WILLIE or any interactive program (execute file).

One will also notice that additional file cabinets have been added for storage and access to the CREATOR package used in the design process. Each file cabinet will hold a certain stage of the design sequence with its drawers catagorizing the information and interactive (execution) files necessary to complete that stage. These will also offer room for expansion in the future as well as cross reference between the cabinets or stages of the design sequence.

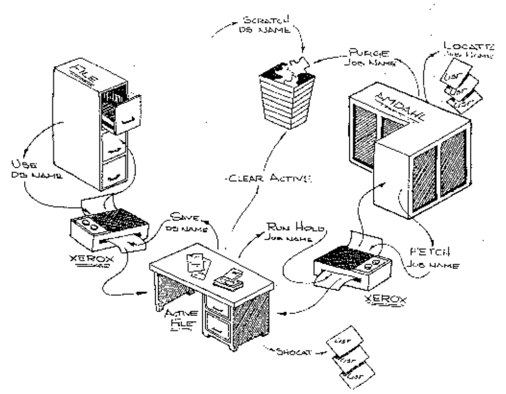


Figure 9. WYLBUR Graphic Aid

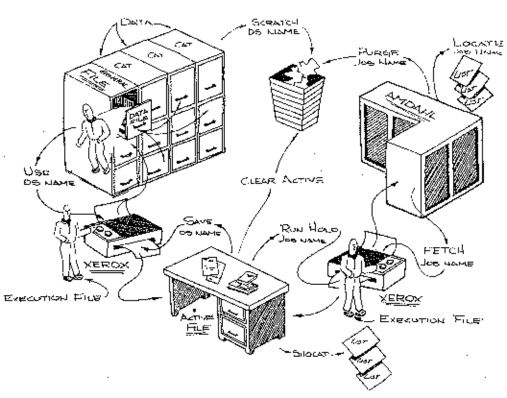


Figure 10. Interactive WYLBUR Graphic Aid

THE ROOM LAYOUT AND WORK STATION

At present, the TAMU graphics classrooms hold 42 students. The classes have traditionally been divided into teams of eight students to work on the design project. A layout or floor plan that might be used to introduce computer-aided design into the design project can be seen in Figure 11. This arrangement would feature one design station for each four to eight students and one for the instructor that would be integrated with the existing television sets. Thus, the instructor can create a picture on his terminal and have it displayed simultaneously on the television sets to show the students what they should see on their terminals. The illustration shows a central computer for the classrooms, but until work has been completed in establishing costs for the various computer and terminal options, it is yet to be decided which types will be utilized. The Hardware Options and Computing Costs section will describe the information that has been gathered as of this time.

The students in the freshman EDG classes now spend about one-third of their time (two hours out of six hours per week) on the design project. With two hour work periods, the students can have at least one-half hour at the terminals per week, or by having teams of two students they can be at the terminal for an hour assuming that one terminal is available for each four students. This system will also require that two out of the present six classrooms be converted to "design laboratories" and each section will have a graphics class in one classroom and a design laboratory in another classroom.

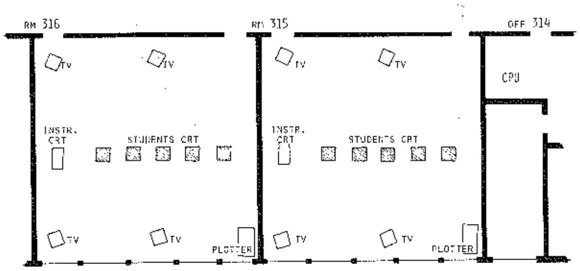


Figure 11. Typical Classroom Floorplan

A typical terminal will be a work station that is composed of an intelligent raster scan refresh CRT and a digitizer board. The hardware will have to be very durable because the arrangement described above will have each work station in use ten hours per day and five days per week. A drawing of the proposed work station is shown in Figure 12. The reasons for choosing the components of the work station are discussed in the next section.

HARDWARE OPTIONS AND COMPUTING COSTS

Three types of computers were considered for use with the design package: the large central computer (Amdahl), the minicomputer (DEC PDP 11/34, Data General Nova, H-P 1000 Series), and the microcomputer (North Star, Cromemco, Imsai, etc.). Three types of graphics terminals were also considered: the storage tube, the intelligent raster scan refresh terminal, and the intelligent vector scan refresh terminal. Of these, the combination which appears to be the best at this time would be the raster scan refresh terminal with either the mini or microcomputer. The cost of the intelligent raster scan terminal is only slightly more than the storage tube and its maintenance costs are about half of the latter ($25-30/mo.). The vector refresh terminals cost about three times as much but do have many desirable features. Costs for 24 raster scan terminals and digitizer boards is shown in Figure 13 under the heading of HARDWARE. This cost for terminals would be the same no matter which computer is used.

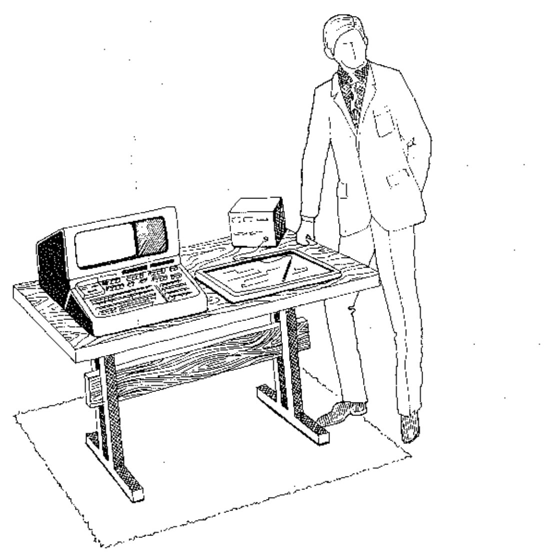


Figure 12. Proposed Design Work Station

MICROCOMPUTERS OPERATION

HARDWARE

Z80A CPU
32K BYTES MEMORY
BASIC LANGUAGE
6 DUAL FLOPPY DISK DRIVES

$5,000.00 PER UNIT
x6 UNITS FOR TWO CLASSROOMS
$30,000.00 UNITS

MAINTENANCE

$50.00 PER MONTH PER CPU
x6 CPU
$300.00 PER MONTH

x12 MONTHS PER YEAR
$3,600.00 PER YEAR

HARDWARE

$5,000.00 PER TERMINAL + DIGITIZER BOARD
x24 TERMINALS
$120,000.00 TERMINALS

$5,000.00 PER PLOTTER - PRINTER
x2 DEVICES
$10,000.00 PLOTTER - PRINTERS

MAINTENANCE

$25.00 PER MONTH PER TERMINAL
x24 TERMINALS
$600.00 PER MONTH

x12 MONTHS PER YEAR
$7,200.00 PER YEAR

AMDAHL - WYLBUR - OPERATION

$1.00 PER HOUR PER TERMINAL
x25 TERMINALS
$25.00 PER HOUR

x10 HOURS PER DAY
$250.00 PER DAY

x5 DAYS PER WEEK
$1,250.00 PER WEEK

x10 WEEKS FOR DESIGN PROCESS/SEMESTER
$12,500.00 PER SEMESTER

x2.4 SEMESTERS
$30,000.00 PER YEAR

COMPARISON OF AMDAHL - WYLBUR OPERATION AND MICROCOMPUTERS OPERATION SHOW THAT INVESTMENTS IN THE LATTER WILL SHOW A BREAK-EVEN POINT AT 3.5 YEARS OF OPERATION.

Figure 13. Cost Comparison-Large Computer vs Microcomputers

Experience showed that TSO ($5-20/hr) was too expensive for multiple users. A cost comparison of the Amdahl (using WYLBUR at approx. $1/hr) and microcomputers over a one-year period can be seen in Figure 13. The operating costs, for one year, on the Amdahl would pay for six microcomputers and although there would be annual maintenance costs, they would not be nearly as much as the operating costs on the Amdahl. Under current conditions, the communications with the microcomputer would be about eight times as fast as with the Amdahl and six microcomputers would support 24 terminals required by the EDG department for the freshman courses. The total cost for this setup for two rooms, including about $10,000 for a printer-plotter for each room, would be about $170,000. This cost should go down somewhat over the next few years as computer hardware costs go down. The maintenance for such a system would be about $12,000 per year. This would be the large portion of a maintenance person's salary and this will be considered in lieu of maintenance contracts. More details are available from the authors on hardware and computing costs but each institution must consider its resources as it makes its choices.

Figure 14 shows the microcomputer and Tektronix terminal used for some of the development work. The microcomputer consists of a Z80A processor, 32 kilobytes of memory, a single disk drive and operates on floating point BASIC.

PLANS FOR THE FUTURE

During the 1979 spring and summer sessions, the software will be finished. This will include modifications to the software already written and writing the new software required for the design process. The components of the design package will be tested in the EDG specialty courses during the spring term. Then, during the summer, one or two design groups in the EDG 105 and 106 courses will use it for their design project. The modifications dictated by the users' experience (teachers and students) will be implemented in the summer or fall sessions of 1979.

Files of equipment brochures with specifications and costs are maintained in order to monitor the latest developments in computer hardware. Thus, specifications for the needed equipment can be easily prepared when funds are made available. It is doubtful that the College of E gineering will be able to fund all the costs of equipping the EDG laboratories and funds will have to be requested from industry. The visiting engineers who come to campus for the freshman design program (EDG 105 and 106) will be given demonstrations so that their companies will be aware of the design package and how it is being used. This should facilitate funding requests to industry.

CONCLUSIONS

The design process has not changed but the speed with which the design is completed and the number of alternative designs which are considered have been increased through the use of the CAD and computer graphics. This plan for having the students use some of the latest computer systems is an attempt to keep up with the current technology. The changes that are proposed here will require the students to know their graphics better than ever before and will require the graphics instructors to stay abrest of the latest technological changes.

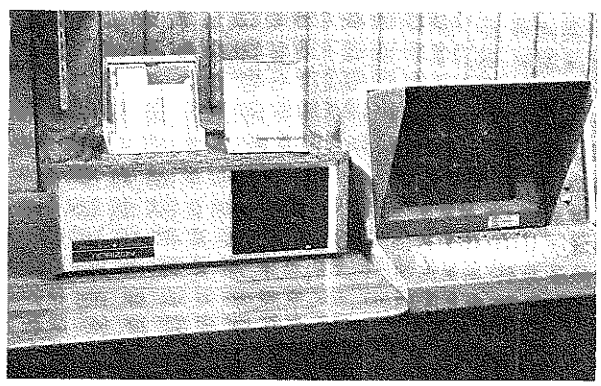


Figure 14. Development System

from the midyear conference...

REVITALIZING THE ART OF GRAPHICS IN MECHANICS

J.M. Henderson
University of California, Davis

S.L. Cotter
University of California, Davis

J.L. Meriam
California Polytechnic State University
San Luis Obispo

The concluding paragraph from a recent article[1] in Science entitled "The Mind's Eye: Nonverbal Thought in Technology" is:

> "Two results of the abandonment of non-verbal knowledge in engineering colleges can be predicted; indeed, one is already evident. The movement toward a 4-year technician's degree reflects a demand for persons who can deal with the complexities of real machines and materials and who have non-verbal reasoning ability that used to be common among graduates of engineering colleges. In the longer run, engineers in charge of projects will lose their flexibility of approach to solving problems as they adhere to the doctrine that every problem must be treated as an exercise in numerical systems analysis. The technician, lower in status than the systems engineer, will have the ability but not the authority to make the "big" decisions, while the systems engineer in charge will be unaware that his nonverbal imagination and sense of fitness have been atrophied by the rules of a systematic but intellectually impoverished engineering approach."

The message of this article is simply that " 'Thinking with pictures' is an essential strand in the intellectual history of technology development".

The authors of the present paper, who represent three generations of teaching and studying mechanics, are concerned by the decline in the use of and emphasis on visualization, perception, conception, and graphical communication in mechanics. Mechanics is a geometric subject; the configurations of structures and machines and the vector quantities that govern their state of rest or motion all require spatial representation. "Thinking with pictures" should become an essential part of the teaching and learning of mechanics. Improving the capacity of students to handle the geometry of mechanics is the focus of this paper.

[1]This article is written by Eugene S. Ferguson, a professor of history at the University of Delaware and curator of technology of the Hagley Museum in Greenville, Delaware; Science, Vol. 197, No. 4306, p. 827, Aug. 26, 1977.

What's the Problem?

The results of the recent national survey of mechanics teaching* and the mechanics readiness test** clearly point to a decline in student preparation in geometry and graphics.

In 1975 the Committee on Curricular Emphasis in Basic Mechanics of the Mechanics Division of A.S.E.E. conducted an extensive national survey of instruction in mechanics. Two of the topics sampled dealt with the extent to which graphics and vector mathematics were in current use. Between 85 and 98 recognized engineering schools responded with the following results:

	Statics		Dynamics	
(Use)	Graphics	Vector Math	Graphics	Vector Math
Significant	4	57	3	72
Moderate	9	17	6	15
Sparing	52	9	41	9
Not at all	21	2	36	2

Although there may be some variation in interpretation as to what constitutes the use of graphics, still the responses clearly show that graphics in one form or another is quite generally used only sparingly, whereas vector mathematics is extensively used. Without minimizing the need for and advantage of developing student ability with vector analysis, especially for spatial problems, it is clear that there has been a significant shift away from graphical portrayal and analysis in favor of the manipulative analysis inherent in vector notation. The systematic bookkeeping of i's, j's, and k's, dots and crosses, and rules for determinant expansions have been substituted in place of graphical-geometrical representations. Considering the basic geometric nature of mechanics and the power which visualization brings to the subject, the trend away from graphical emphasis is considered to be a significant loss which by no means has been offset by the gain in manipulative knowledge of vector notation. Students should be encouraged to gain a working knowledge of vector analysis, but it should disturb us when they lose the facility to formulate and communicate through visualization.

What is needed in mechanics instruction is to strengthen through graphical emphasis the capacity of students to visualize and then couple this ability with effective use of vector mathematics. Without a doubt the

*Engineering Education, Vol. 67, No. 3, Dec. 76, p. 249.
**The Mechanics Readiness Test - A Study of Student Preparedness for Mechanics, by Virgil Synder, Michigan Technological University, and J.L. Meriam, California Polytechnic State University. (Presented before the annual meeting of ASEE, Vancouver, B.C., June 20, 1978.)

students who make the best use of vector mathematics are those who have been able to visualize the graphical and geometrical significance of that mathematics. This balance of emphasis on both graphics and mathematics needs revitalized attention in today's mechanics classrooms.

Strong evidence of the weakness of current students in the geometric side of mathematics has been revealed by the Mechanics Readiness Test, sponsored by the Mechanics Division of A.S.E.E. This test was taken by over 9000 second-year engineering students enrolled in 4-year engineering programs throughout the country in the fall of 1977. Out of 25 technical questions covering elementary concepts, mainly in mathematics, 20 of them depended in large measure on geometric configurations. Considering the elementary nature of the questions, a score of 80 percent would be a reasonable expectation for students with a normal background in algebra, geometry, trigonometry, and beginning calculus. The national average, however, was a shocking 51 percent, indicating that current students have not had sufficient drill in the physical and geometrical applications of mathematics to prepare them for the analyses required in mechanics and other engineering subjects. This inability to handle the geometry of simple mathematics also reflects in considerable measure their lack of training in graphical skills. Most perceptive teachers of mechanics have observed that a student is better able to calculate a geometric relation if he or she can draw it clearly.

To ensure meaningful learning in mechanics teachers need to place emphasis on the most important aspects of the subject, and the geometry and graphics of mechanics should be considered as basic fundamentals. Teachers should set good examples in all areas of representation and should develop their own skills in graphical portrayal, especially when using the blackboard as a primary means of communication. The "do as I say, but not as I do" approach has no place in the teaching of mechanics.

In most mechanics problems, as in the majority of problems of engineering analysis and design, the first important step is a sketch or other graphical expression of the given situation. It is at this point that the direction of the analysis usually takes shape. It is said that people fall into two general categories - word people and picture people. Engineers are essentially picture people who must deal directly with position, form, and motion. For them, graphics is a vital skill and we should do all we can to develop this capacity.

Consider now several specific examples of the advantage and need of graphical portrayal. Figure 1 includes a typical statics problem and a properly organized and presented solution.[2] The graphical portions of the solution embodied in the free-body diagrams were developed prior to the mathematics and therefore served as a correct guide for the rest of the solution. The understanding of the quantitive portions of the solution is greatly facilitated by the graphical portrayal of the problem. Two dynamics problems recently assigned in one of the author's classes are

[2]Henderson, J.M., and Meriam, J.L., Study Guide for Engineering Mechanics, Statics, Kendall/Hunt, 1978.

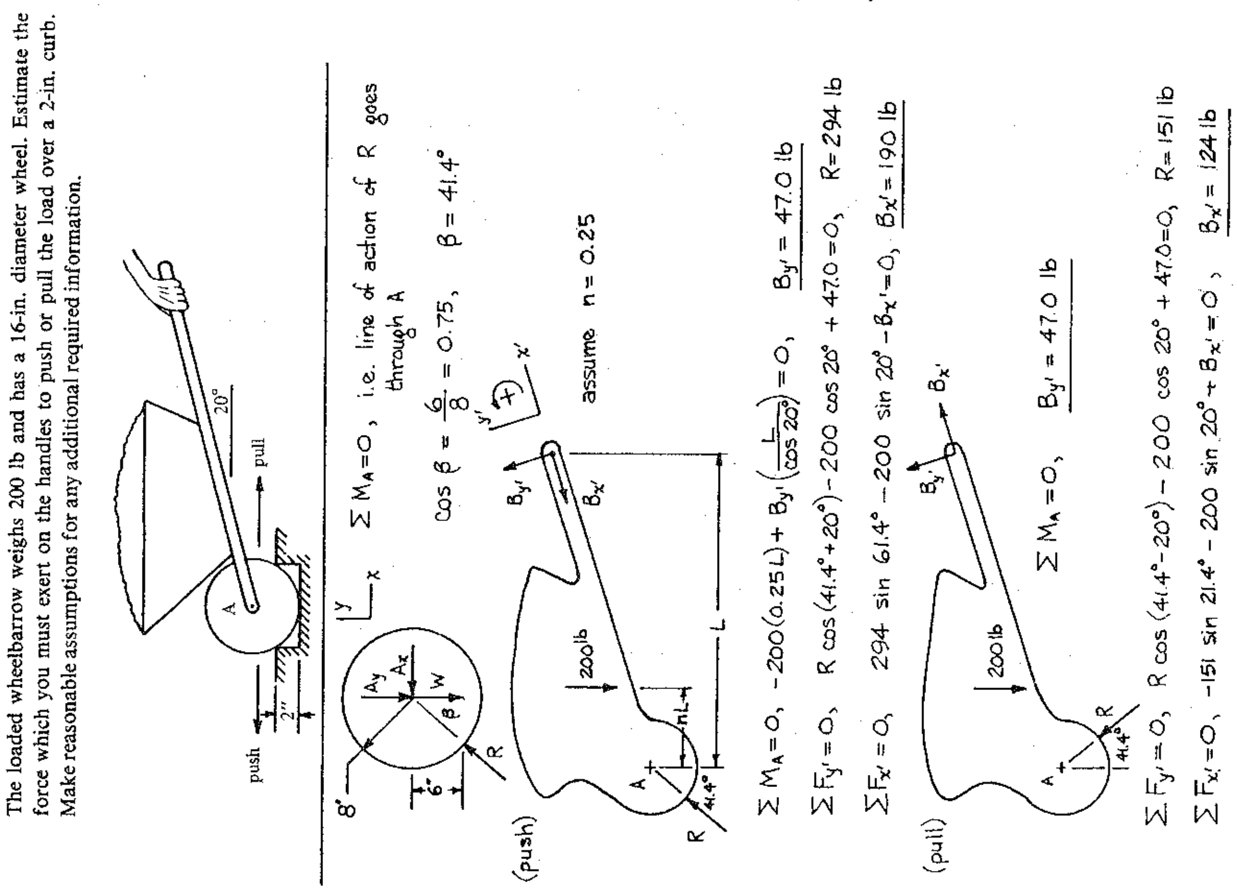
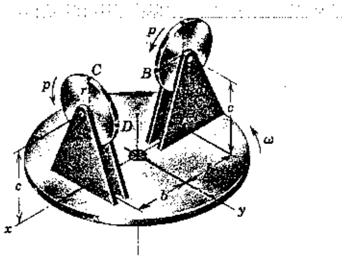


Figure 1 - A typical statics problem and solution

The large disk turns about its central vertical axis with a constant angular speed ω in the direction indicated. The small disks in turn spin about their horizontal axes at the constant angular speed p relative to the large disk in the directions shown. Determine the expressions for the accelerations of points A and B at the instant represented.

Ans. $\mathbf{a}_A = b\omega^2\mathbf{i} + 2rp\omega\mathbf{j} - rp^2\mathbf{k}$
$\mathbf{a}_B = [(b - r)\omega^2 - rp^2]\mathbf{i}$



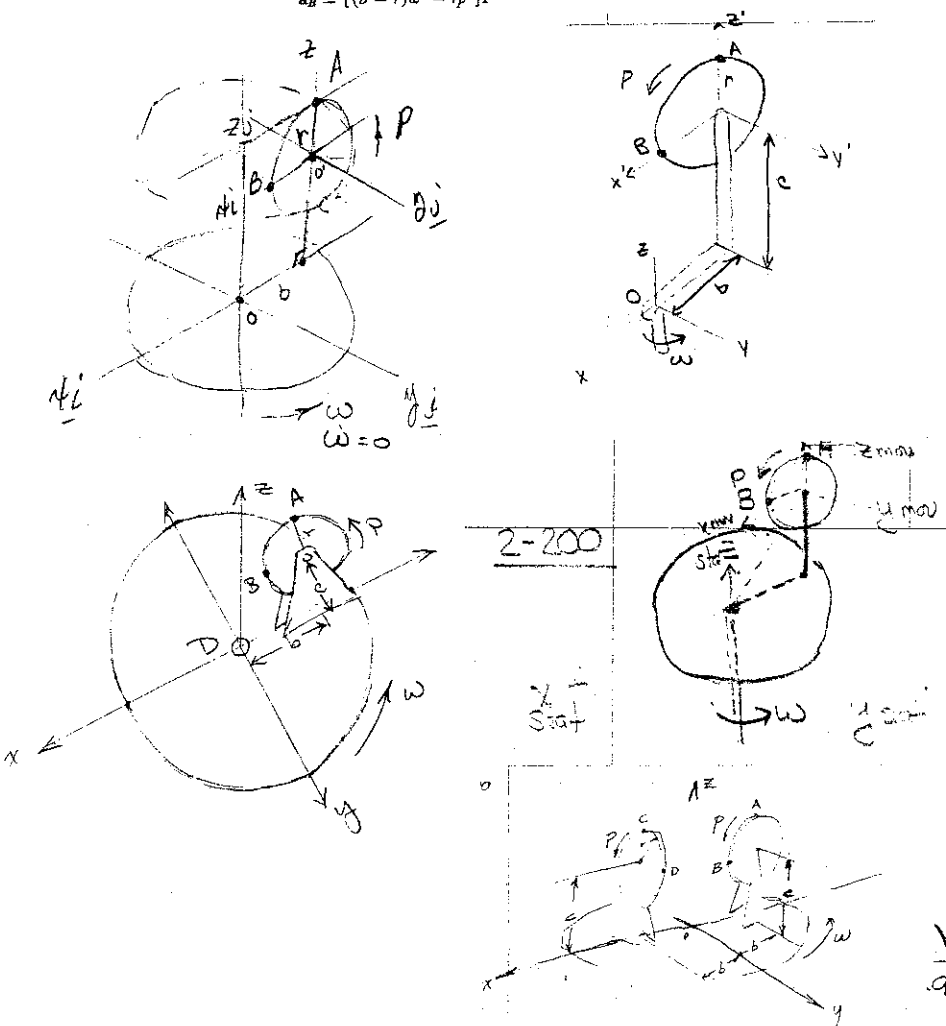
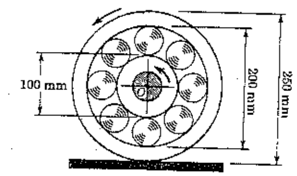


Figure 2 - Examples of student sketches (Problem 2/200, Meriam, Dynamics, Second Edition, SI Version, Wiley, 1975)

The large roller bearing rolls to the left on its outer race with a velocity of its center O of 0.9 m/s. At the same time the central shaft and inner race rotate counterclockwise with an angular speed of 240 rev/min. Determine the angular velocity ω of each of the rollers.

Ans. ω = 10.73 rad/s clockwise



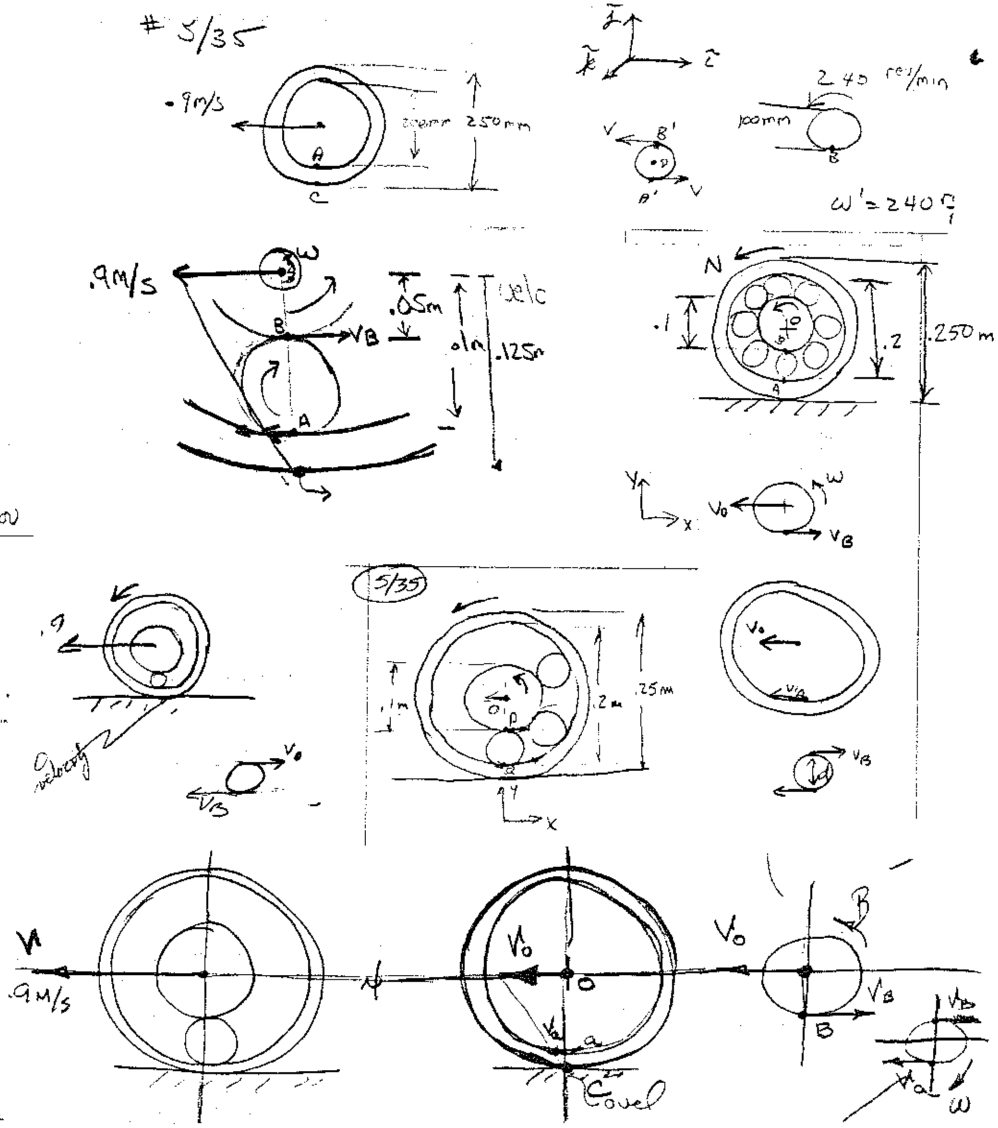


Figure 3 - Examples of student sketches (Problem 5/35, Meriam, Dynamics, Second Edition, SI Version Wiley, 1975)

shown in Figures 2 and 3 along with sample portions of several solutions submitted by the students. All the examples are work done by typical students who were fully capable of understanding the concepts involved. The conclusion is obvious; the students do not value and/or do not have proper facility with graphical representation and communication, and this lack is a decided handicap to them.

Sketching Skills

To visualize an object in three dimensions, and hence to better interpret its spatial situation, facility with isometric, oblique, and perspective sketching is of tremendous value. Note the clarity of the free-hand sketches shown in Figure 4. A good sketch reveals the significance of the physical actions by and on the body, and reveals any geometry which must be described.

Artistry in sketching should not be discouraged but is certainly not a prerequisite to effective graphical representation. The construction of sketches using only a few rules of graphics can be executed effectively without artistic talent. For example, representation of acute angles (other than 45° angles) as either greater or less than 45° so as to distinguish clearly the sine from the cosine when calculating components is a useful graphical technique.

Very few students seem to know how to represent a circular object, such as a wheel on a shaft, or the end of a cylinder, in a pictorial sketch. The right-angle relation between the shaft or cylinder axis, and the major diameter of the ellipse, as shown in Figure 4, has not generally been taught. This simple observation has a dramatic effect on the portrayal of circular objects.

Emphasis on sketching in mechanics and other engineering courses has a much broader effect on students' abilities than merely expediting the solution of problems assigned in the course. Graphic facility serves as a vital intellectual and creative step in bringing concepts and ideas into reality, as well as a help in describing and understanding existing and proposed ideas and concepts. Sketching is a vital extension of an engineer's mind.

Computer graphics is a rapidly expanding area that is usually introduced to engineering students in machine design or optimization courses relatively late in their undergraduate careers. The ability to visualize and represent spatial objects using the principles of descriptive geometry or pictorial representation can also be greatly strengthened through the use of computer graphics. Two of the authors have observed the effective use of an interactive graphics program and cathod-ray tube display. All beginning graphics courses could benefit by including this type of opportunity for students as it offers an effective way to develop their skills of spatial visualization.

Mathematical Analysis

Mathematics is probably the most important tool of an engineer. Much of the mathematical analysis used by engineers is graphical or geometrical by origin. The primary link between most physical situations and their resulting mathematical model is developed through the choice of an axis system. How many students can choose an appropriate axis system where the choice rests primarily on existing geometric convenience?

In using vector operations such as the cross-product representation of the moment of a force about a point, it is essential that the student be able to visualize the spatial geometry of the cross product in graphical terms, as indicated in Figure 5. In mechanics, the routine manipulation of symbols, such as the determinant expansion for the cross product, is devoid of meaning (and usefulness) when the geometric significance of the operation is not fully understood.

The geometric representation of vector addition with a vector polygon reveals at a glance the full significance of the vector equation involved and brings to light the meaning of each step in the solution. The method of solution could be trigonometric, graphical, or vector algebraic; all three solutions have their place, and a good sketch of the vector combination brings all three approaches into perspective. For example, the solution of a typical relative acceleration equation for plane motion might be illustrated by the equation

Jerald henderson's talk at the recent midyear conference,"The Need for Graphics in Upper Level Engineering Courses", was based on this paper, which he delivered at the 1978 Annual Conference in Vancouver. He presents an excellent argument here for development of graphic abilities, and led the way to an exciting and thought-provoking session at Mississippi State. That entire session is included here, as promised in the Winter issue. This paper, along with the following two papers and their accompanying commentaries, will give the interested reader some real food for thought!
Paul S. DeJong, P.E., ed.

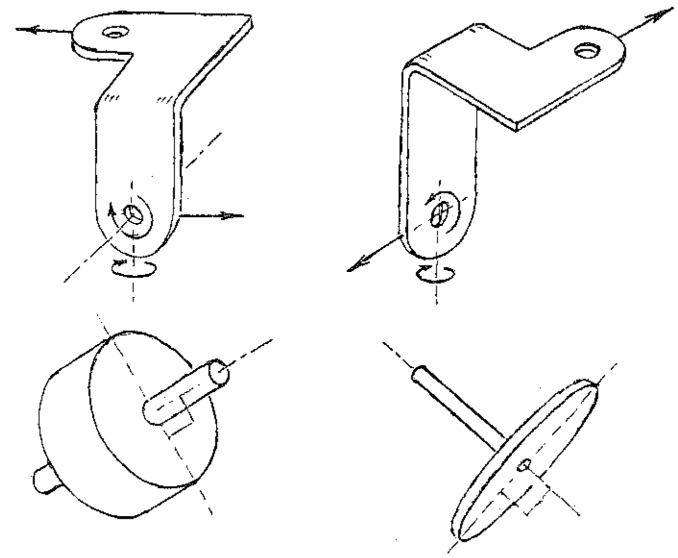


Figure 4 - Some good free-hand sketches

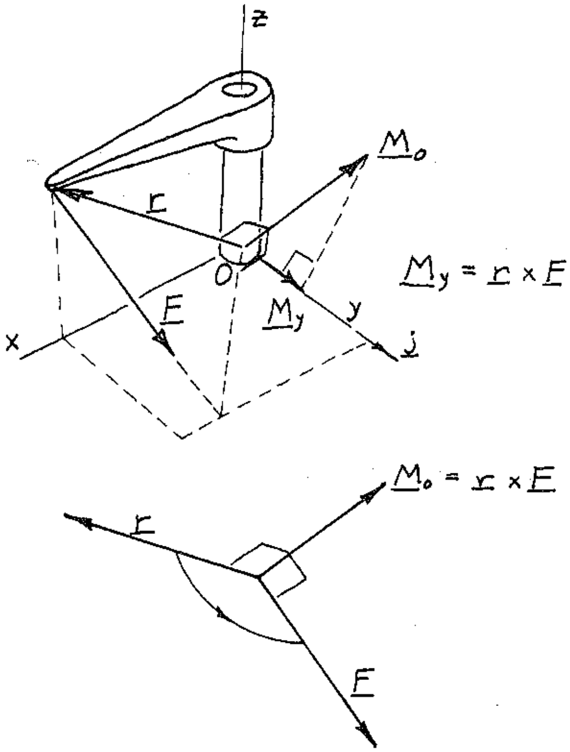


Figure 5 -

Representation of the geometry of the moment of a force about a point and about a line

$$\underline{P} = \underline{V}_1 + \underline{V}_2 + \underline{V}_3 + \underline{Q}$$

where the Vs are known vectors and P and Q are known in direction only. After the relationship is portrayed graphically as shown in Figure 6, the advantage of summing components normal to P or normal to Q to avoid the necessity of simultaneous equations can be fully realized. A vector algebraic solution, on the other hand, will invariably lead to simultaneous equation for a problem of this kind. Also, the choice of a trigometric or graphical method of solution can be made easily.

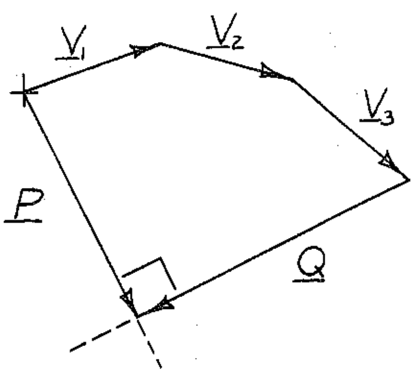


Figure 6 - Example vector polygon for a plane motion problem

Frequently, when there are several ways to develop a concept in spatial representation, a graphical approach can bring out central ideas in a simple and intuitive way. In contrast, an algebriac, "grind-it-out" approach, although systematic, can often cause one to lose sight of the point of the entire development. In addition, algebraic mistakes are common and often difficult to catch. This contrast is especially evident, for example, when dealing with directional derivatives in spherical coordinates. In this case the problem is to find

$$\frac{\partial \hat{r}}{\partial r}, \frac{\partial \hat{\theta}}{\partial r}, \frac{\partial \hat{\phi}}{\partial r}, \frac{\partial \hat{r}}{\partial \theta}, \frac{\partial \hat{\theta}}{\partial \theta}, \frac{\partial \hat{\phi}}{\partial \theta}, \frac{\partial \hat{r}}{\partial \phi}, \frac{\partial \hat{\theta}}{\partial \phi}, \frac{\partial \hat{\phi}}{\partial \phi}$$

in terms of r, θ, ϕ and the unit vectors $\hat{r}, \hat{\theta}, \hat{\phi}$ shown in Figure 7. Algebraically, the easiest way is to express the unit vectors $\hat{r}$, $\hat{\theta}$ and $\hat{\phi}$ in terms of the unit vectors $\underline{i}$, $\underline{j}$ and $\underline{k}$, then differentiate and re-express in terms of the spherical unit vectors. Take $\partial\hat{r}/\partial\phi$ as an example:

$$\hat{r} = \cos\phi \cos\theta \, \underline{i} + \cos\phi \sin\theta \, \underline{j} + \sin\phi \, \underline{k}$$

$$\frac{\partial \hat{r}}{\partial \phi} = \sin\phi \cos\theta \, \underline{i} - \sin\phi \sin\theta \, \underline{j} + \cos\phi \, \underline{k}$$

so $$\frac{\partial \hat{r}}{\partial \phi} = \hat{\phi}$$

Figure 7 shows how this same result can be obtained graphically with less complication and more clarity.

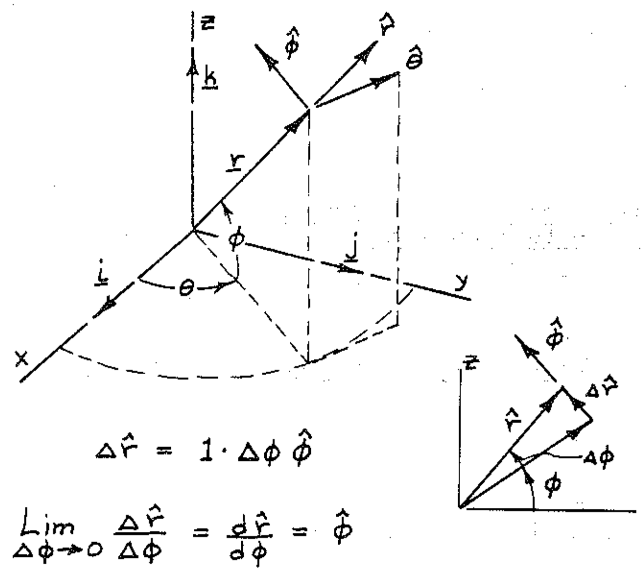


Figure 7 - A directional derivative in spherical coordinates

Mechanics Instruction

There has been a trend to develop the symbolic and manipulative side of the theory of mechanics without first developing adequately the physical and geometric understanding of the problems. Without geometric understanding the symbolic and manipulative concepts have little value, especially in the teaching of elementary mechanics.

The identification of three-force members in equilibrium problems, and the associated concurrency point, is greatly facilitated by a graphical portrayal of the situation. The concept of stability can be easily defined and visualized using the familiar graphical representation of the potential function where the total potential energy V of a body is shown as gravitational potential energy as in Figure 8. Important stability characteristics can then be readily identified by visualizing the motion of a marble resting on this "potential surface."

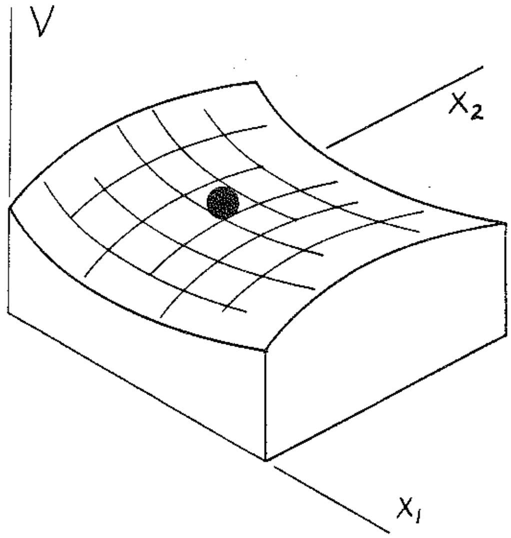


Figure 8 - Representation of a potential surface

The use of a rotating axis system and the resulting Coriolis acceleration term is often a major source of misunderstanding for mechanics students. Differentiating a position vector twice will give the correct expression for acceleration but offers little help to the student in understanding the physical significance of the "2 $\omega \times u$ " term. Once a student obtains a physical understanding of the Coriolis term, then a wide variety of problems can be handled analytically with accuracy and understanding. We suggest that the following straight-forward graphical presentation is a significant help in understanding what usually is obtained by formal differentiation. The straight rod in Figure 9 rotates about one end with a constant angular velocity ω relative to the rod. By looking graphically at how the velocity vector changes from time t to time t + Δt one can see the two contributions to the Coriolis term. This simple example clearly shows how the Coriolis term comes from the rotation of the path and position change of the slider on the path. Once these ideas are understood by students, then problems with more geometric complexity can be handled more successfully.

Graphics can be used to give one an intuitive feeling for an analytic concept. An example of such a concept is the product of inertia. Even without arriving at an exact formulation, much can be learned from investigating the magnitude and sign of the product of inertia $I_{xy} = \int xy \, dm$ by examining simple

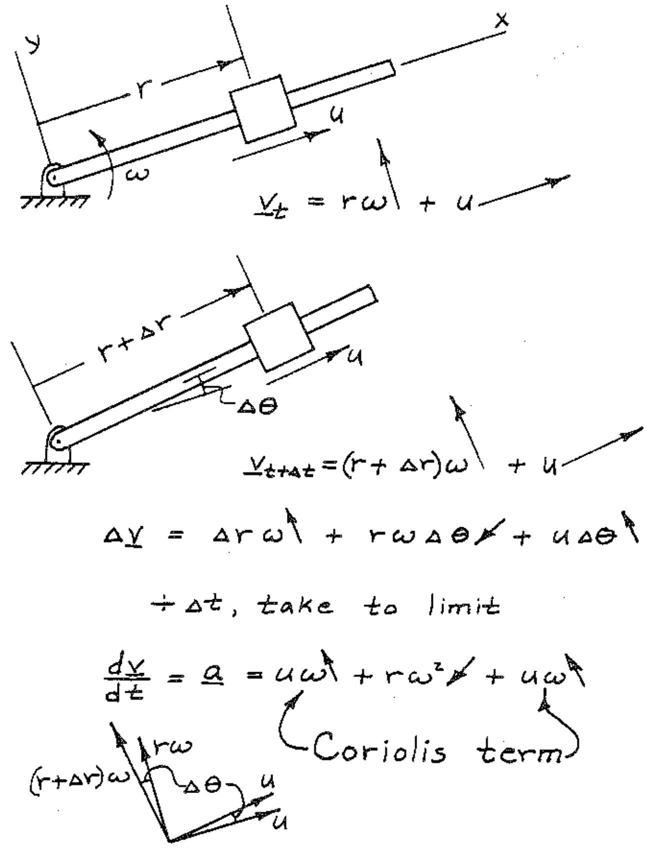


Figure 9 - The Coriolis problem

sketches, keeping the mathematical formulation in mind. Consider the thin rod oriented several ways in Figure 10. Cases (a) and (b) are positive and the value of (b) is larger than (a). Cases (c) and (d) are zero and case (e) has a negative value for I_{xy}. These simple graphical examples give a visual "feel" for what the orientation of the body implies about the product of inertia.

Conclusion

If the purpose of mechanics instruction was merely to train students to solve existing problems, there might be more justification to center our efforts on the routine, manipulative aspects of mechanics problems. However, the objectives of instructors should extend far beyond the routine solution of the existing

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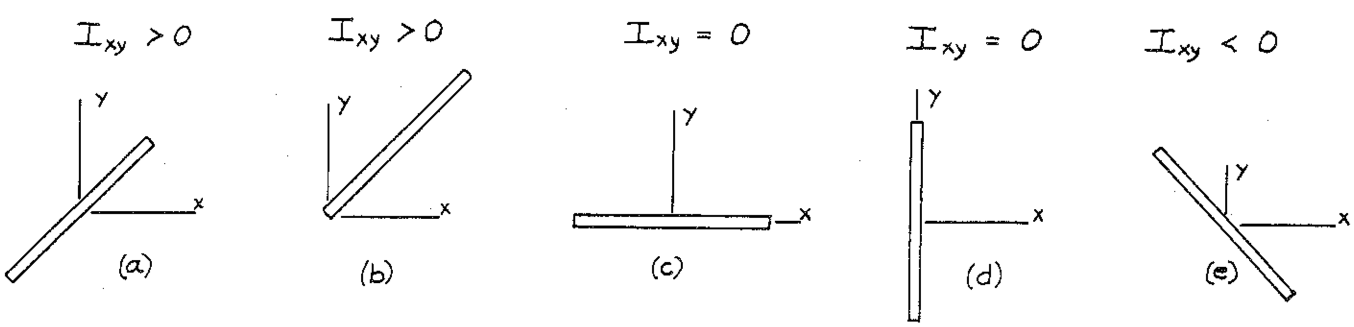
Figure 10 - Products of inertia



from the midyear conference...

WHO NEEDS GRAPHICS?

Karl A. Brenkard, Dean
School of Engineering
University of Mississippi

Before we consider the question of engineering graphics, I would like to review some history of engineering education in the United States. This history will consist of five reports and some World War II experience. In 1920, the Wickenden report was released. He set a goal for engineering education as professional education. He recommended post scholastic experience as a cooperative effort between the schools of engineering, industry, and professional engineers. He really defined a rather narrow education. Having done this, he then turned around and said we must have a broad education by saying, "Engineering is not a sharply defined professional field, but one of a wide range of types and levels of activity which should enlist a correspondingly wide variety of individual talents. It needs the one-talent, the five-talent, and the ten-talent man. The most obvious defect in our present general scheme of engineering education is its inflexibility, in that it affords little alternative to the standardized four-year program of our engineering colleges."

This was the beginning of the recognition of the basic problem of engineering education - whether to be a narrow, professional education, or whether to be a broad, general education.

As a result of the Wickenden study, unfortunately, no coordinated post scholastic experiences were invorporated. Diversity came to be all-inclusive: if an engineer needed to know something about management, add a course in management. As engineers must work inside a social structure, add social sciences and humanities - and this went on and on.

As a result, the engineering courses became very practical and engineers were taking many hours which were at the expense of basic sciences and mathematics.

There were two Hammond reports, one in 1940, the other in 1944. Hammond leaned toward more diversity. He said, "Engineering educators should not limit their aims to preparing young men for professional registration and practice." Having established a breadth of education, he then hedged by saying, "Advanced training for the higher technical levels should be included in the general program of engineering education but should not become its dominating aim." In 1944 he recommended increased emphasis on basic science, humanities, and social sciences. Again, instead of coming out with a direct answer he vascillated by saying, "To weaken the educational base of professional study would, of course, defeat our entire purpose." Thus he gave us no solution to the problem of professional versus general education.

By 1952 when the Grinter Report came out, engineering education was in a turmoil. We required anywhere from 10-15% more hours than the other baccalaureate programs. The report itself recommended a return to the basic sciences with a definite commitment to humanities and social sciences. In a way it completely sidestepped the issue of the professional education versus the general education. Actually, it recommended a strong bifurcated program in which some of the schools would be strongly science oriented and some of the schools would be strongly professionally oriented. But he made the mistake of leaving the impression that the schools such as MIT, Michigan, Cal Tech, Wisconsin, Stanford, etc., would be highly science oriented schools and somewhat less well known schools would be professional schools. As there were very few deans who did not want to have a school as good as MIT, almost everybody went for the engineering science program. So we ended up again with no solution to the professional education versus the broad general education problem.

The general result of this was an increase in science and math and more humanities and social sciences. This was done by reducing the content in professional engineering and in design. Thus the traditional ideas of a professional engineering school were completely lost sight of.

In 1969 the ASEE Report of Goal of Engineering Education, which I will call the Walker Report, recommended a pre-engineering program for the general education and a fifth year for the professional education. To me this seems like a logical solution to the problem of general education versus professional education. After all it is the same route that was taken by the well recognized professions of law and medicine.

Unfortunately, very few schools were willing to drop their four-year programs for the first professional degree. This made it very difficult for other schools to go to a five-year program. Consequently, today we stand in the same position that we stood in in 1920. We have no solution to the question of professional education versus general education.

In the Second World War there were many innovations of science that were brought to bear in the war effort. Innovations such as radar, jet engines, and nuclear bombs. Unfortunately, when it came to the engineering of this equipment, the engineers did not understand enough of the basic science to do the job and so the main engineering was done by physicists and chemists. This was one of the reasons that the Grinter Report recommended increasing basic sciences and math in the engineering program.

Where are we today? We have the same basic struggle between professional engineering and general engineering. The National Society of Professional Engineers is trying very hard to bring back the professional concept to engineering education, but the professional path has still not accepted the pre-engineering-engineering five-year concept. My personal opinion is that we have gone too far toward general education andwe are not educating our engineers in the professional concepts of engineering.

With all this history, what should this have to do with graphics? The role of the engineer has changed - instead of working on a drawing board turning out drawings showing his design, the engineer has become a general technical problem solver, with technicians and computers doing the final and detail drawings. Today we are more concerned with developing the mind of the engineer and less with developing his skills as a machinist, draftsman, etc.

Does this mean that the engineer has no need for graphics? The advancement of the high speed computer certainly means that the graphic solutions are obsolete. However, the engineer still must be able to communicate his ideas to other engineers, to technicians, and technologists. He must be able to read drawings and he must be able to communicate his ideas. Therefore, we must teach him how to read and communicate via graphics. It is the contention of the engineering scientists (at least this one) that this can be done in a one-semester course. We do not need to teach him to be an artist, which is what we tried to do in the 30's.

The demands of science, mathematics, engineering science, humanities and social science, and engineering design in the student's program are such that it is impossible to offer any graphics without deleting some course that is more important. The continuing expansion of knowledge will make this situation worse not better. Therefore, I see not an expansion of engineering graphics in the engineering curriculum, but a continuing fight to keep it from being eliminated altogether.

COMMENTARY ON DEAN BRENKARD'S PRESENTATION

My disagreement (from the floor on 4 January 1979) with Dean Brenkert's position that one semester of spurious formal instruction is sufficient for an adequate coverage of the rudiments of engineering graphics was not a wild shot from the hip, fired to attract attention, but a carefully aimed barb at all those in positions of administrative authority who have a gross misconception of what constitutes "functional literacy" in this subject area, and the time and effort required to develop minimal competency in the beginning engineering student. Over the past thirty years, I have had a close association with engineering graphics instruction to include teaching in the classroom, writing instructional material, and planning, organizing, and supervising educational programs which included engineering graphics. During this time I have had the opportunity of and responsibility for monitoring the progress of nearly thirty thousand first-year students of engineering graphics through programs organized in a variety of time frames. I cannot prove my subjective contention that one semester (3 credits, six hours) is woefully inadequate for developing a "functional literacy" in engineering graphics, but I have considerably more confidence in my empirical judgment than in, what appears to me to be, a superficial and somewhat biased opinion.

I understand and appreciate the Dean's (any Dean) responsibility for maintaining a tight rein on subject matter specialists who are constantly lobbying for more time for their parochial interests. With a fixed amount of time available, it must be carefully apportioned to favor the most essential elements of the total program at the expense of the merely desirable. And this is what bothers me. Engineering Graphics, along with mathematics, physics and chemistry, is one of the four cornerstones upon which a sound engineering education is based. To construct a super-structure of sophisticated academic courses on a foundation lacking or weak in one or more of its major elements is to seriously shortchange both the student and the engineering profession. In recent years I have had some contact with young engineers with graduate degrees from "prestigious" engineering schools who were in fact functionally illiterate in the graphic language, and even worse, were blissfully unaware of that ignorance until called upon to perform some routine task which required a basic understanding of a set of engineering drawings. I suggest that engineering administrators put aside preconceived (and perhaps mistaken) notions. Find out what is and should be included in a present-day engineering graphics program. Find out how an adequate preparation in graphics can significantly reduce some of the learning difficulties in more advanced courses. Find out what employers expect the new engineering graduate to know and be able to do. Find out what constitutes functional literacy in engineering graphics, and how much time is realistically needed to acquire the rudimentary knowledge and basic skills. I fear that, unless something is done soon to rebuild this crucial cornerstone of engineering education, the entire superstructure is in danger of collapsing from its own weight.

William B. Rogers
Professor, Engineering Fundamentals
Virginia Polytechnic Institute and State University
Blacksburg, Virginia

from the midyear conference...

THE TOTAL CONCEPT OF GRAPHICS AND DESIGN IN THE ENGINEERING CURRICULUM

Dr. Charles W. Newlin
Dames & Moore, Consulting Engineers

Graphics is an important part of the engineering curriculum because it is a vital communication process for engineers. Graphics is to engineering as english composition and grammar are to a novelist. An engineer often thinks in terms of graphics and visualizes problems solutions graphically. Not only do engineers communicate with one another through graphics, but it is important for clear and accurate communication with the public the engineer serves.

I am associated with a large consulting firm which specializes in environmental engineering and earth sciences. Prior to assuming my present position, I spent 25 years in civil engineering education.* My comments to justify the importance of graphics in engineering are based on these experiences with practical examples drawn from soil engineering projects.

Graphics is an integral part of design and design is the key element that differentiates the engineer from the scientist. Designs are visualized and presented graphically; thus, an individual who has not developed a feeling for graphics cannot function effectively as an engineer. He or she must be able to visualize a problem in both two and three dimensions. Let me give you an example. An earth dam is normally analyzed for stability and seepage by working with a typical cross-section through the dam. This section may be properly analyzed but if the third dimension of the dam is overlooked failure could result from undetected discontinuities at another cross-section or in the abutments. An engineer experienced in visualizing problems in three dimensions is less likely to make a mistake in this type of problem.

An outstanding session was held this morning where various aspects of computer graphics were discussed. It was pointed out that engineers now have the capability of direct dialogue with computers by viewing the graphical output and observing the response that a structure would have to changes in geometry or material properties. There are those who have said that the emergence of the computer has decreased the need for training of engineers in graphics. What could be farther from the truth? Computer graphics is putting the emphasis back on problem visualization where it belongs and away from the drudgery of numerical computation. The really valuable engineer is the person who uses computers as a tool so that efforts may be concentrated on vital engineering decisions. Graphical displays produced by a computer are useless unless the user can interpret the significance of the display. The advent of computer graphics has simplified the engineer's work because it eliminates the need to make the mental conversion from numbers to graphics.

Another example drawn from recent soil engineering experiences involved a subsurface water pressure relief system from a dry dock. The solution of the seepage equations for such a problem can either be obtained from a relatively sophisticated computer program or can be sketched by hand. Both approaches could be used effectively but my practice in this area is to never rely exclusively on the computer solution even though the results give greater precision. When the flow net is sketched, the engineer gets a gut feeling for the problem and for how flow would be altered if certain boundard conditions or parameters are changed. In addition, incorrect computer output may be easily detected. Freehand sketched flow nets are a graphical solution of seepage problems that are a valuable aid in the visualization of a physical phenomenom. Often seepage problems are so complex that it is impossible to sketch a flow net; however, soil engineers generally will visualize the solution of such problems in terms of a flow net even though

* Prof. & Head, Civil Engineering Dept., Arizona State University.

they never put pencil to paper. The dry dock problem was solved solely by the application of flow nets -- a necessity in this case because the work was conducted in a remote location where there was no access to computers.

If an engineering problem isn't described graphically, it must be described either verbally or mathematically. To overemphasize any one approach is a mistake. For example, I am concerned about the trend toward mathematical descriptions at the expense of graphics in engineering education. There are those mechanics teachers who feel that there is no need to draw a freebody diagram because they feel that statics problems are adequately described by the equations of statics. Others do not teach Mohr's circle because the state of stress at a point can be described mathematically. My experience, like many others, is that if I can sketch the freebody diagram, I have the problem solved; also, there is no need to remember the equations for the two dimensional state of stress at a point because they can be obtained directly from the graphical representation.

Why has there been a reduction in the graphics content of the engineering curricula in recent years? In my opinion, the answer to this question can be obtained by looking at what has happened to design in the engineering curricula since graphics is an integral part of design. In my opinion, there were two major factors involved: (1) Sputnik, and (2) the increasing bureaucracy in educational institutions. The reaction of engineering education to Sputnik is well-known. The mathematical and scientific content of programs was increased without increasing the number of credit hours for graduation. As a result, traditional engineering courses had to be eliminated. Design courses were some of the first to go. Scientifically oriented faculty members were in demand and the number of scientists on engineering faculties increased. Federally sponsored research became a major controlling factor in the financial planning of schools. Scientific research was the carrot held before young faculty members so it was a natural reaction that their interests should move away from design even though they might have been trained by design oriented faculty.

As universities became more bureaucratic, decisions on salaries and promotions were taken away from the Department Chairman and placed in the hands of committees. With the decision making remote from the individual, decisions were based on criteria that could be documented. Does he have a PhD? How many papers has he published? How many research dollars has he brought to the university? In such an environment, the new faculty members that were hired were young PhDs without practical experience who were interested in scientific research.

We are now in the third or fourth generation of faculty whose primary interest is scientific research. The PhD remains a requirement for new faculty and these faculty have been brought up in an environment where the design philosophy was deemphasized. At the graduate level, we have PhDs training PhDs to train other PhDs. I do not wish to imply that doctoral degrees and research are not a vital part of the engineering education system. Instead, it is my opinion that the educational pendulum has swung too far in the direction of mathematics and science and objectives could be better achieved by bringing it back nearer dead center.

In conclusion, I would like to cite a fact of life that is central in the operation of a consulting firm. We deal directly with the public and our only product is written reports. These reports are signed by registered engineers who attest to the validity and form of the reports. Since the document consists in large part of graphical representations, how can an engineer fulfill his obligation to the public without having a firm foundation in graphics?

COMMENTARY ON DR. NEWLIN'S PRESENTATION

Charles Newlin pretty much hit the nail directly on the head with his presentation at the Division's Annual Mid-Winter Conference at Mississippi State. 'Tis a pity that those of us in attendance at the meeting and readers of the Engineering Design Graphics Journal are the only ones who are exposed to his theme - and most of us don't really need the reminder!

Perhaps the most interesting, and no doubt most controversial, segment of his remarks addresses the recent evolution of engineering education. Having departed a distinguished career in engineering education to devote full energies to the practice of engineering, Dr. Newlin is in an excellent position to assess the impact of recent trends. Research and subsequent publications have become the Holy Grail to be sought after at any cost. It is the life blood of the faculty, without which tenure and promotion cannot exist. The teaching (or what passes for teaching) of undergraduates has become a methodology to spawn future graduate students for more research and still more publications. Does it really matter that the huge majority of these same undergraduates will not go on to graduate school but must go forth to engineering practice with only a baccalaureate degree? Wouldn't it be great if government, the source of most of our research funds, were to emphasize the practical application of current knowledge to the solution of problems by approving significant funds to support and improve undergraduate teaching? You may have recognized a widely accepted definition of engineering in the previous sentence.

Thanks for your message, Charlie Newlin.

W. George Devens, P.E.
Professor, Engineering Fundamentals
Virginia Polytechnic Institute and
State University

from the midyear conference...

A METRIC AMERICA: WHY HAVEN'T WE GOTTEN THERE SOONER?

Klaus E. Kroner
University of Massachusetts

Although metrication is making good progress in some isolated sectors of our society, the effort for the U.S. as a whole is dragging along at an incredibly slow pace. It is the purpose here to identify some of the reasons for this situation and to suggest that we, as individuals, need not wait for government guidance or edicts in order to contribute our share to this national goal.

Hans J. Milton, who is active in the official metric conversion effort in Australia, gave a talk at the June 1978 Annual Conference of A.S.E.E. in Vancouver, in which he correctly pinpointed some basic causes for the slow progress towards conversion. He stated:

> "It has been said that the greatest obstacle to metrication is lack of awareness of people, or ignorance. The 'natural resistance to change', that is so common to all people, is readily exploited by a few anti-metric commentators and leaders who feel that they are preserving heritage and traditions when they oppose change. In general, the anti-metric group seems to be poorly informed on the concepts that underlie measurement, whether it be in metric units or in customary units. Their predictions of costs and problems are wild and extravagant guesses, but not factual. Some groups have adopted a 'future--not present' approach, designed to postpone metrication out of reach of the immediate time frame".

One might add to the causes which he mentions, the lack-luster and foot-dragging attitude of the Congress as well as anti-metric stances taken by certain government agencies, as shall be illustrated later.

Without reviewing the relatively long history of earlier attempts to encourage the U.S. to adopt the metric system as its predominant system of measurements, let it be noted that in 1968 the Metric Study Act led to the formulation of a federal report published in 1971 entitled "A Metric America, A decision Whose Time Has Come". Four years later this was followed in Congress by the passing of Public Law 94-168--the Metric Conversion Act of 1975--and the eventual appointment of the U.S. Metric Board in 1968, as had been called for in the '75 legislation.

It is useful at this point to briefly review the eight major recommendations of the above mentioned report of 1971 and note any progress made for each of them. The recommendations were as follows:

1. "The United States should change to the international metric system deliberately and carefully through a coordinated national program". --This suggestion has not yet been carried out as we have no coordinated national program as of this date.

2. "The Congress should establish a central coordinating body to guide the change". --The U.S. Metric Board was finally appointed for this purpose in 1978.

3. "Detailed conversion plans and timetables should be worked out by the sectors themselves within this framework". --Thus far only some individual corporations and a few federal agencies have developed such plans.

4. "Early priority should be given to educating school-children and the public at large to think in metric terms."
--Considerable progress is being made in many states towards educating the children, but metric training for the adult population is woefully lacking.

5. "Immediate steps should be taken by the Congress to foster U.S. participation in international standards activities."
--What limited participation has taken place and has been encouraged by industry trade groups rather than Congress.

6. "Any conversion costs should lie where they fall".
--This has been widely accepted as an appropriate policy, although these potential costs have often been greatly exaggerated.

7. "The Congress should establish a 10-year time frame for the United States to become predominantly metric".
--The Act of 1975 did not mention a time frame at all.

8. "There should be a firm government commitment to convert".
--With the possible exception of the N.B.S., there are presently few commitments by government agencies. Where specific conversion plans had been announced, some of them have been retracted (Fed. H'way Adm.) or delayed (Nat. Weather Serv.).

While looking for other examples of obstacles to a deliberate and speedy conversion to metric, along came a Report To The Congress by the Comptroller General of the U.S. General Accounting Office in October 1978 entitled "Getting A Better Understanding of the Metric System--Implications If Adopted by the United States". This 39 mm thick document and its companion Executive Summary are designed to cast doubt on the wisdom to change, and twist certain events or misinterpret other writings so that the reader is bound to arrive at erroneous conclusions. Even the title implies that the metric system may not be adopted, and a statement on the cover includes the sentence: "Whether the Nation's measurement system should be changed is a question still unresolved". This is in direct contrast to the intent of the Metric Conversion Act of 1975 in which Sec. 3 it specifically states that:

"It is therefore declared that the policy of the United States shall be to coordinate and plan the increasing use of the metric system in the United States and to establish a United States Metric Board to coordinate the voluntary conversion to the metric system."

In Sec. 6 we find that:

"It shall be the function of the Board to devise and carry out a broad program of planning, coordination, and public education, consistent with other national policy and interests, with the aim of implementing the policy set forth in this Act".

It is quite clear from the language in the Act that it was indeed the intent of Congress in 1975 to encourage the speedy and coordinated change to the metric system and provided for the means of accomplishing this--namely the procedure for establishing the U.S. Metric Board. Yet, the authors of the Report conclude: ".....it is not the current United States policy to convert from the present customary system to the metric system."

The GAO Report cited a case of unfair trade practices in connection with the changeover; specifically, hidden price increases of distillery products as the industry changed to metric size bottles. This is the only instance documented, yet the tone of the narration implied hat price gouging was wide-spread and to be blamed on the changeover to metric.

Many observations in the Report, however, were fairly recorded. To quote a couple of these:

"A majority (60 percent) of the largest U.S. industrial businesses--the Fortune 500--who responded to GAO's questionnaire believed conversion would facilitate trade...."

"General Motors has found that as more experience is gained in metrication, conversion cost estimates decrease. For example, General Motors estimated in 1976 that its metrication costs will range only between 3 and 4 percent of its original estimate made in 1966."

Both state and educational agencies and engineering education received good marks in the GAO document. Among other statistics, the target dates for predominantly metric instruction in 23 states were listed, with thirteen of them scheduled for 1980. The American Society for Engineering Education, and particularly it's Metrication Coordinating Committee, were cited as having come out strongly in encouraging metric instruction in engineering schools.

However, some professors which were interviewed by the GAO warned that "...national conversion will be slow because many of the decisions which will influence its progress will be made by those who have not been given sufficient reasons to change" and "the beauty and logic of the system is not enough to sell it. We need national commitment and marketing people to promote it." It would appear that the authors of the GAO Report are examples of what is alluded to in the first of these two quotes. Perhaps they were influenced by the positions taken by labor and small business--two sectors who have never given their wholehearted support to the metrication effort. The second quote would indicate a need for the U.S. Metric Board to engage top-notch public relations firms to promote acceptance and conversion among the general public. The argument expressed in the GAO Report that the Board must refrain from favoring one measurement system over another is just not acceptable. Why have a coordinating body at all, if it is not allowed to pursue its change vigorously and be free from such unrealistic hurdles. Thus, the GAO Report states many facts, though not all, quite correctly; but the conclusions, especially as stated in the Executive Summary, are not valid reflections of those facts and give a distinctly negative impression about the entire metrication effort. What is particularly distubing about all of this is the fact that most potential readers will study only the Executive Summary and give relatively little attention to the main report which contains a more appropriate assessment of the entire matter (if only the cover could be ignored).

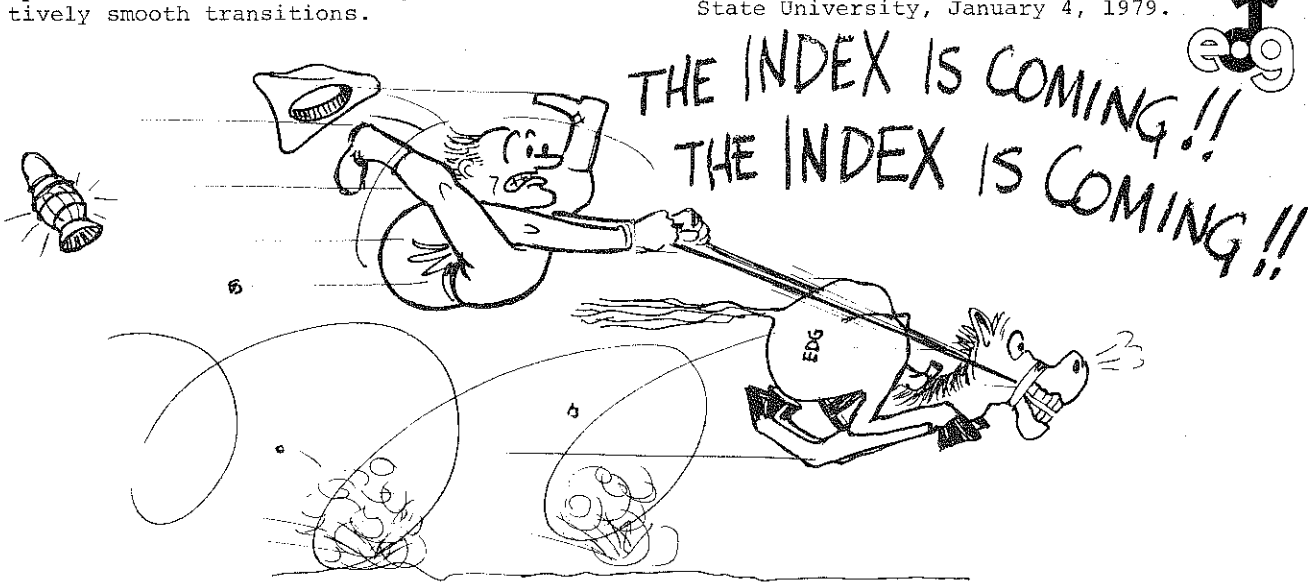
Turning to a different subject, a recent issue of the Metric Monitor (published by the Metric Commission, Canada) showed that public opinion toward metric conversion grew increasingly in favor of it during the metrication process both in Canada and Australia. In both countries the governments provided effective leadership and worked under a specific time frame to accomplish relatively smooth transitions.

Small group or even individual efforts can often result in the initiation of metrication without awaiting government edicts or guidelines. Already in the early 70's metric speed limit signs went up beside their customary counterparts in the city of Huntsville, Alabama, due in part to the presence of large numbers of scientists who had long been familiar with metric measurements. Another example is the erection of directional road signs on a college campus (Univ. of Massachusetts) expressing the distances in kilometers as well as miles, and the indication of wall lengths in meters on the walls of selected classrooms. These projects were the direct results of a self-appointed faculty metric committee.

The author recently used the occasion of a real estate transaction to have the surveyor draw the plot plan with a metric scale, metric contour lines, and the lengths of the property lines expressed in meters. The surveyor was most happy to oblige after ascertaining that a plot plan drawn to metric units was a perfectly legal document in the affected government jurisdiction. Most such professionals are well acquainted with the metric measurements and are pleased to use both.

In summary, it can be said that this country could and should be making much more progress toward becoming predominantly metric. Certain agencies and sectors of our economy can be identified which are deliberately sabotaging the road to a smooth transition. This resistance and delay is truly not in the best interests of U.S. trade, domestic or foreign. Better progress will result from intensified educational and training programs as well as by individual efforts to help the public to understand and properly use SI. It is the hope that this country will not much longer be that foreign island in a metric world.

This article is based on a talk presented by the author at the Mid-Winter Conference of the Engineering Design Graphics Division of A.S.E.E. at Mississippi State University, January 4, 1979.



from the midyear conference...

Edward V. Mochel
University of Virginia

" GOING SI "

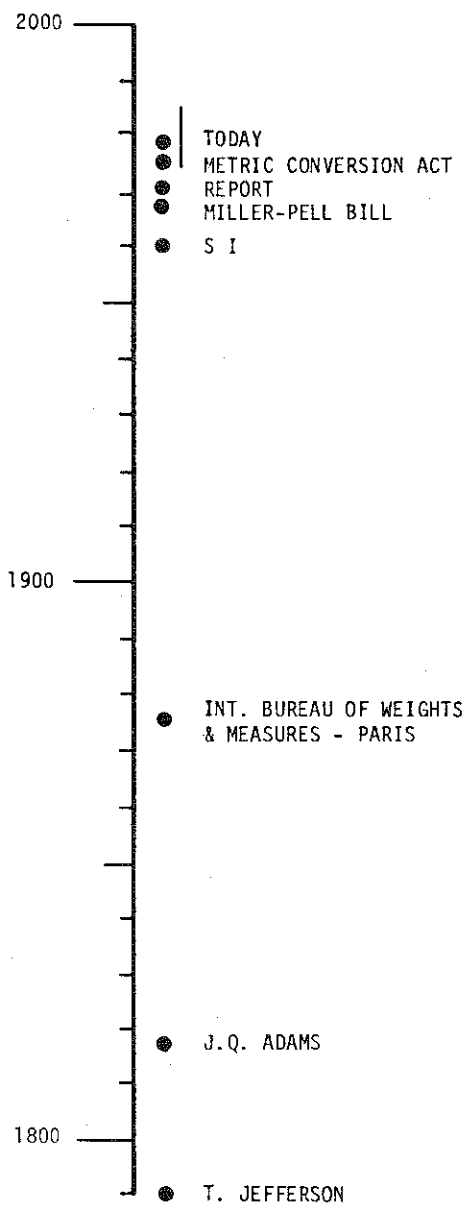


Figure 1. Chronological display of Metric Events Affecting the U.S.

The title of this paper started as "Where Are We Going," but since I believe we are "Going SI," the paper will concern itself with two related questions. They are...

(1) how fast are we going?
(2) what path will we follow?

To establish a perspective on where we are going, at what rate and by what path, Figure 1 shows a time scale with some metrication events on it. The first dot at the bottom of Figure 1 shows the date of 1790 when Secretary of State, Thomas Jefferson, recommended to Congress a system similar to the French system using decimal arithmetic throughout. Congress ignored this recommendation.

In 1817 John Quincy Adams, also Secretary of State, began a four year study recommending the metric system. This study was also ignored upon completion.

In 1875 at the International Metric Convention in Paris, 15 nations established a permanent bureau, still in existence, to handle all international matters concerning the metric system.

Those who attended the Midyear Conference will immediately realize that this material is similar to a Paper given at Starkville, Mississippi on January 4, 1979. Ed is an entertaining speaker and provided this wealth of information in a most enjoyable way. You will find the paper good reading. The question that occurred to me then occurred to me again here: Are some faculty members really half - SI'd?

Paul S. DeJong
Editor

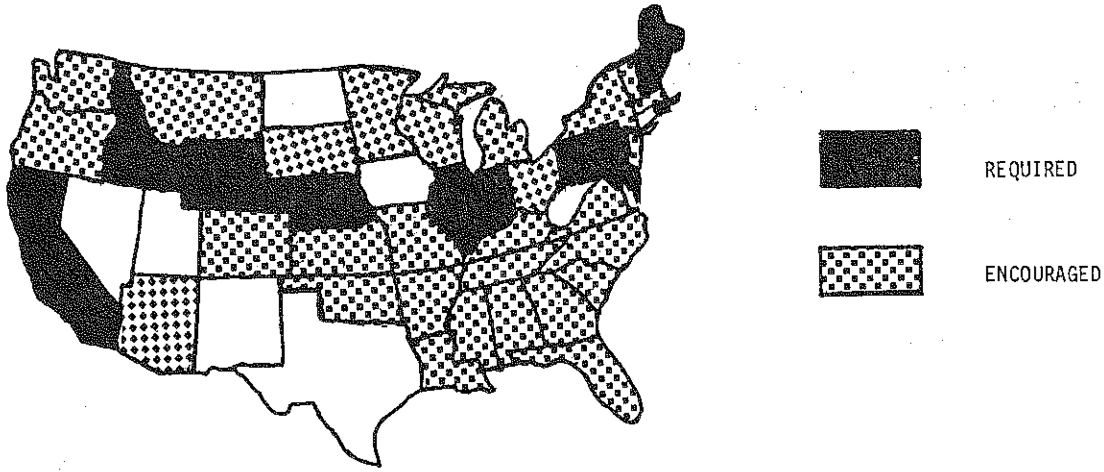


Figure 2. State Educational Systems Policy Toward SI in 1976.

In 1960 this group, the General Conference on Weights and Measures, formally titled the system "International System of Units" abbreviated as "SI". The United States was one of the 36 nations participating in this move.

In 1968 Congressman Miller and Senator Pell put a bill through Congress directing the Secretary of Commerce to investigate costs, procedures, implementation of metrication.

The report of this study came out in 1971 titled "A Metric America, A Decision Whose Time Has Come".

In 1975 the Metric Conversion Act was passed by Congress which involves an approximate ten year changeover period. We are about one-third of the way through this period.

The vertical bar in Figure 1 represents this ten year span. The 1975 Act provides:

(1) voluntary changeover.
(2) costs lie where they fall - no subsidies.
(3) ten year period (estimated)
(4) establish a U.S. Metric Conversion Board.

This concludes establishing where we are historically with respect to SI in the United States.

Now I will attempt to depict what the picture of metrication is at present for educators, or what path we can follow.

The results of a recent survey[1] reported in the Journal of Engineering Education show that

11 states require metric education in public schools,

28 states encourage metric education in public schools, and

11 states have no provision or did not respond to the questionnaire.

This information is shown in Figure 2. This means that students will be coming to college already familiar with SI and will expect to continue using these units.

Another article[2] in the Journal of Engineering Education by Paul Berrett, past chairman of ASEE's Metric Coordinating Committee contained the following recommendations for engineering educators:

(1) Although textbooks in SI are not available in all subjects, departments should convert data in the textbook problems to SI and require students to solve the problems using SI rather than convert the answer.

(2) At least half of all examinations or quizzes should be in SI as a start.

(3) A changeover of laboratory equipment to SI should be planned, both modifying old equipment and purchasing new.

(4) It is of the utmost importance that the changeover be to SI and not to some garbled metric system.

(5) Require that each student and faculty member have a copy of ASTM E 380-76. This is available from the American National Standards Institute as Z 210.1 for $4.00 per copy.

(6) People must be told that this is <u>not</u> a European system, or the old metric system, but that it is a <u>new</u> system, barely 18 years old.

(7) The <u>coherence</u> of SI must be stressed. The <u>new</u> units and the system of writing them must be stressed. The units which have been eliminated must not be used.

(8) Departments should conduct seminars on SI for both students and staff. SI should be presented by film or slides

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1 J.E.E. April 1977, page 674.

2 J.E.E. April 1977, pages 672-3.

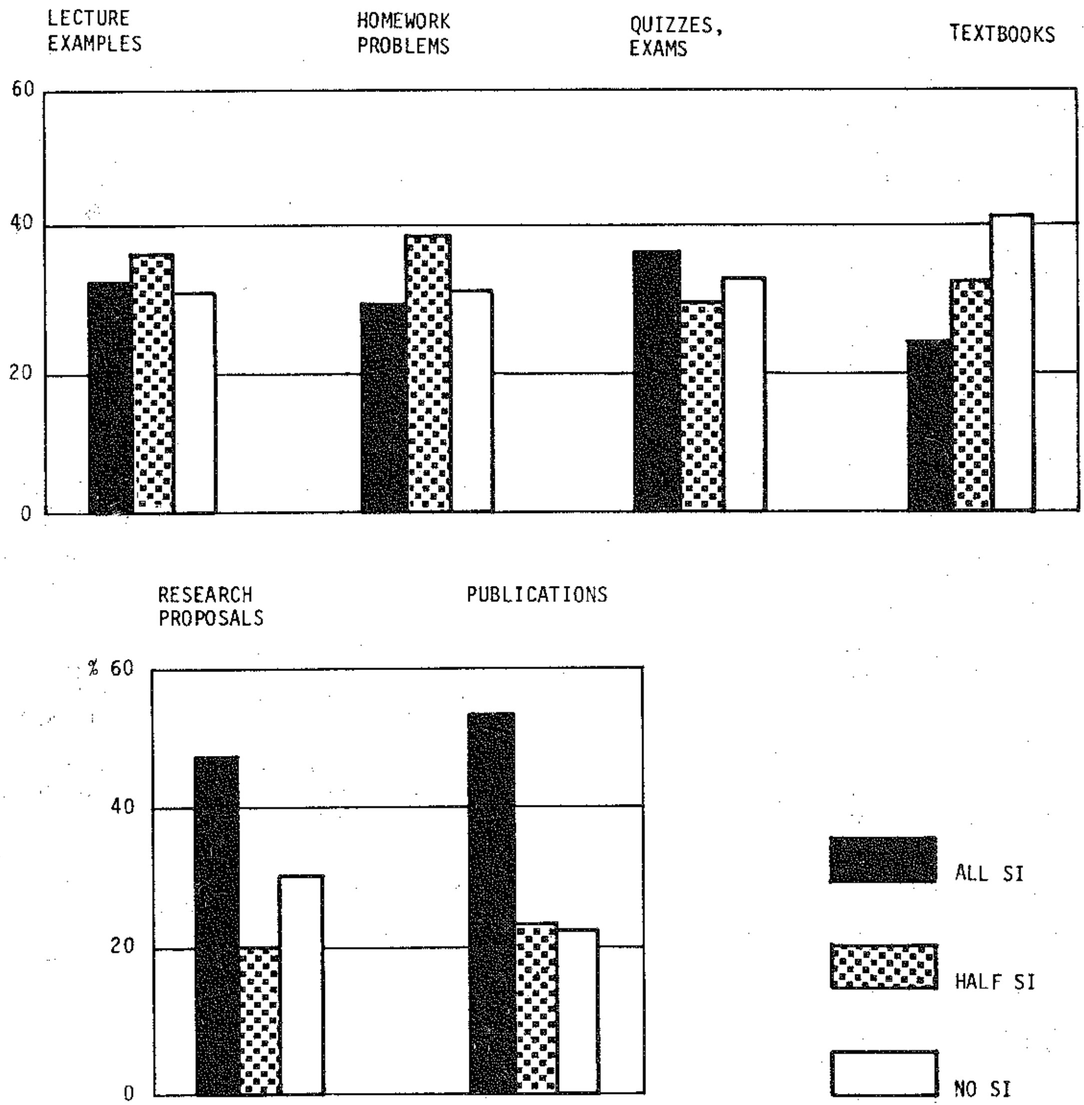


Figure 3. Results of a Faculty Survey at University of Virginia in 1977.

Table 1	Almost All/All S I Units	About Half S I	Very Little S I
Used in lecture example in courses	32	36	31
Used in homework problems	29	39	31
Used in quizzes, exams	37	30	33
Used in present textbooks: for Fall 1977	27	33	40
for Spring 1978	23	33	43
Used in research proposals	48	21	31
Used in publications in last year	34	24	23
		YES	NO
Have copy of ASTM "Standard Metric Practice" 1976		50	50
Use this for reference		45	55

to the whole engineering faculty at a scheduled faculty meeting, as well as to students. Posters can be made up for placement through schools to advertise SI. Making up posters, comic or serious, could be projects for pledges to the honorary societies.

(9) Be sure to proceed with reason, in a spirit of helpfulness, and not to be too critical of the mistakes of others.

Gene Mechtly of the University of Illinois, Chairman of the Metrication Coordinating Committee of ASEE, listed the following timetable for SI in engineering courses in a recent memo:

MOSTLY SI AT PRESENT

Statics, Dynamics
Fluid Mechanics
Thermodynamics
Heat Transfer
Design Graphics

1979	Strength of Materials
	Machine Design
1980	Structures
1983	Concrete Design
1984	Construction Design

This past year I circulated a questionnaire among the engineering faculty at the University of Virginia. The questionnaire was an attempt to find out how the faculty was progressing in changing to SI units. Eighty of the 120 faculty members returned the questionnaire, and the results are shown in Table 1; all values are percentages. The same data are shown in Figure 3.

The November 1978 issue of Journal of Engineering Education had a questionnaire on page 164 on SI units entitled "Checking Your SIQ" by George F. Hauck, University of Missouri. I took the questionnaire and asked five other members in my department to take it. The results were a range of 42% - 68% correct with a 52% median and 54% average. Thus, we answered a little better than half correctly. After this poor showing, I tried to analyze the common errors, and summarize what knowledge was lacking. I recommend the following:

(1) Obtain a good reliable, recent source, such as ASTM E 380-76.

(2) Learn the seven basic units names and symbols.

(3) Learn the names and symbols for the derived units you use in your work.

(4) Memorize some rules of punctuation. For example, don't use capital letters for a name (meter) or symbol (m) unless the name is a proper name (Celsius), symbol (C). Don't use a period after a symbol.

(5) Learn the prefixes which serve as multipliers. Examples: prefix (kilo), symbol (k), multiplication factor (10^3), example: Kilometer, symbol (km).

(6) Try to think in terms of SI units in your daily life. Learn your height, weight, etc. in SI units.

If you are willing to invest a couple of hours time and have an open mind, conversion to SI will be a relatively easy experience. I suggest you test your SIQ, and this will help you diagnose what areas you need to study.

The calligraphy on page 31 is another example of the fine work of Gretchen Weber, Iowa State University.

The one
important thing
I have learned
over
the years
is
the difference
between
taking one's work seriously
and
taking oneself
seriously

The first is
imperative
and the second
disastrous.

DAME MARGOT FONTEYN

GW
79

R. D. Jenison
Iowa State University

1979 ANNUAL CONFERENCE PREVIEW

Again in 1979 the Engineering Design Graphics Division has planned a busy and interesting series of events for ASEE members and guests during the Annual Meeting at Louisiana State University June 25-28. Let us look briefly at the program highlights to help you plan your schedule for the conference. See the accompanying timetable for day and time of each event.

TECHNICAL SESSIONS

EVENT 1648 - The technical sessions kick off with a distinguished panel discussing administrative structures for freshman engineering programs. This session, moderated by Larry Northup from Iowa State, should provide a wealth of information in an area that is receiving a great deal of attention at this time. A portion of the session is reserved for audience comments and questions.

EVENT 2552 - Frank Jankowski from Wright State moderates a session on human factors in engineering design. This session has been a part of EDG's program for several years and is highlighted by speakers from industry. See page 34 for more information.

EVENT 2645 - Mary Jasper from Mississippi State has put together a fine program on freshman year design, a topic that has been missing from our program recently. You will learn directions of design in the first year.

EVENT 3238 - Some of the latest developments in teaching engineering graphics will be presented in this session moderated by Amogene Devaney. A lot of successful innovations in teaching never become known. Here is a great chance to learn directly from the innovators.

EVENT 3544 - Francis Mosillo, University of Illinois - Chicago Circle, presents another program on the popular subject of computer graphics. His speakers will report on recent developments in computer graphics education.

EVENT 3634 - This is a new topical area for EDG programs - Computer Programing for Undergraduate Engineers. Blaine Butler, Purdue University, has assembled a fine group of speakers, including two from industry, for this session on what should constitute the first computing course for engineers as well as uses of programming techniques by undergraduate and beginning practicing engineers. This should be a very informative program.

CO-SPONSORED EVENTS

Three events of interest to EDG Division members are being co-sponsored. If your busy schedule will allow, plan to take in one or more of these.

EVENT 1827 - Rap Session on Creativity sponsored by Engineering Design Committee.

EVENT 2293 - Metric Standards sponsored by Metrication Coordinating Committee and moderated by Ed Mochel.

EVENT 2559 - CAD/CAM in Engineering Technology sponsored by Engineering Technology Division.

CREATIVE DESIGN DISPLAY

Be sure to look for the room with the Design Display which will be open Monday afternoon to Wednesday noon. See the design projects submitted from all levels of engineering students in the keen competition for first place. The EDG Design Committee has put forth a great deal of effort in securing a distinguished group of judges and providing the format for our students to present their projects.

BUSINESS AND MEAL EVENTS

To conduct the business of the EDG Division, several combined meal and business sessions are scheduled. If you are new to the Division, you can best become acquainted by attending the Annual Awards Dinner (EVENT 2734) and the Business Luncheon (EVENT 3434).

EVENT 1144 - Business meeting for Design Committee and Creative Design Display judges (closed).

EVENT 1738 - EDG Division Executive Committee (closed).

EVENT 2734 - The Annual Awards Dinner. Meet and greet old and new friends and join in the fun and fellowship (and some business) of the EDG Division's highlight occasion of the year.

EVENT 3434 - Annual Business Meeting and Luncheon. The business activities of the past year and upcoming year are presented in an informal atmosphere.

As you plan your "Southern Vacation" this year to Louisiana State, consider attending as many of the Division events as you can. Your support by attendance will help insure more fine programs in the future.

ENGINEERING DESIGN GRAPHICS DIVISION - ANNUAL PROGRAM EVENTS

TIME	MONDAY, JUNE 25	TUESDAY, JUNE 26	WEDNESDAY, JUNE 27	THURSDAY, JUNE 28
7:30 a.m.	1144 ↓			
8:00 a.m. to 9:45 a.m.	↓	(2293)*	3238	
10:00 a.m. to 11:45 a.m.	13XX: Mini Plenaries	2300: Plenary Session	33XX: Mini Plenaries	43XX: Mini Plenaries
12:00 noon to 1:30 p.m.			3434	
1:45 p.m. to 3:30 p.m.		2552 (2559)*	3544	
3:45 p.m. to 5:30 p.m.	1648	2645	3634	
Dinner	1738 ↓	2734 ↓	ASEE Reception Honors Assembly ANNUAL BANQUET ↓	
Evening Sessions	(1827)* ↓	↓	↓	( )* = co-sponsored event

EDGD to SPONSOR ANNUAL CONFERENCE SESSION ON HUMAN FACTORS ENGINEERING AND COST PARAMETERS IN ENGINEERING DESIGN

EVENT 2553

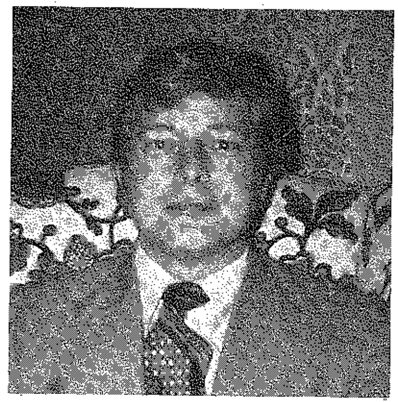
Many engineering programs focus on equipment performance as the most important design parameter. That approach may have been satisfactory in the previous decade. However, with the ever-increasing operational and support (O & S) costs, it has become imperative that these costs be considered at the earliest stages of system design. Human resource factors account for the majority of the O&S cost so it is necessary to bring these factors to bear early in the design process. These human resource factors are: personnel, manpower, training, and other support resources.

Much work has been done to develop a comprehensive approach to achieve the above objective. Although the process application is somewhat involved, the concept is straightforward. The first speaker, Dr. Andrew J. Czuchry, will highlight the main features of the process with a simplified example. Material will be provided that could be utilized in the classroom to illustrate how O&S costs can be reduced when human resources considerations are utilized to influence engineering design decisions.

The second speaker, Donald Phelps, of NCR, will discuss and illustrate how human factors and operational and support costs are important to industry and must be factored into engineering design.

Finally, Dr. John Kreifeldt of Tufts University will discuss the implications for engineering education. His thesis is that engineers, both new graduates and those continuing their education, will be more effective if they have an appreciation and understanding of how human resource considerations can be utilized to influence engineering design decisions.

This Session will be held on Tuesday, June 26, 1:45 - 3:00. See the Conference Program for location.



BIOGRAPHICAL SKETCH

Dr. Czuchry received his PhD in Electrical Engineering from the University of Connecticut in 1968. He is a member of the senior staff and is currently serving as Director, Advanced Systems for Dynamics Research Corporation. Dr. Czuchry developed a total systems approach for solving a broad spectrum of logistics and human resource problems. This approach provides a methodology for influencing engineering design decisions based upon total system support requirements. He has been a major contributor on more than 20 military and civil programs. He has 15 publications and more than 25 Government technical reports. He received the USAF Systems Command Technical Achievement Award in 1973.

BATON ROUGE!!

Jobs

Purdue University, West Lafayette, Indiana, has available two faculty positions at the instructor or assistant professor level in the Engineering Graphics area of the School of Engineering, for appointment beginning August 1979. The MS degree in engineering or a closely related area is required. Candidates with the following qualifications will be given preference: Industrial experience or related teaching experience and active participation in appropriate technical societies; the ability to coordinate beginning drafting courses with different discipline objectives; and the ability to work with students, faculty, and administrators in a broad academic environment. Applicants should have interest to advance in more than one of the following areas: representations by computer aided drafting, numerically controlled manufacturing, electrical and electronic design, construction systems, photo and mapping, or industrial illustration. Send resume and references to Professor K. E. Botkin, MGL 103, Purdue University, West Lafayette, IN 47907, before 1 June 1979. Salary dependent upon qualifications. Purdue University is an Equal Opportunity/ Affirmative Action employer.

IMPACT OF OVERLAY TRANSPARENCIES IN ENGINEERING GRAPHICS INSTRUCTION

Dr. R. Meenakshi Sundaram
Tracy B. Nabers

Old Dominion University
Norfolk, Virginia

INTRODUCTION

During the past two decades engineering faculty all over the country have been under immense pressure to reduce the total number of semester hours of study and to include new technological developments in the curriculum at the same time. This has resulted in a drastic reduction in number of credit hours for application type courses such as Engineering Graphics. It is a matter of record that in most engineering schools, Engineering Graphics courses have suffered a loss of six semester hours -- from nine semester hours to three. Although the fresh engineering graduate is generally no longer expected to work on the drawing board he or she is often expected to possess the engineering graphics skills as a design and communication tool. For some time the engineering graphics faculty have been concerned about the development of this skill in the engineering students. Frankly, the current level of skills developed during a one-semester engineering graphics course does not seem to be adequate for the job demands of a mechanical design engineer. The dilemma: How to develop the required knowledge and skill within one semester? Two solutions seem to surface. They are: (a) use of educational technologies in instruction; and (b) use of self-paced instruction coupled with brief classroom instruction. This research study is concerned with the use of transparencies - a tool of educational technology - as potentially effective and efficient instructional media in Engineering Graphics education.

Basically, the experimental design of the study was the presentation of a series of very well-planned and organized presentations making use of lecture and blackboard sketches and a second series utilizing commercially available transparencies with well-planned and completely integrated lectures. Subjective observations were made by the instructor concerning the speed, ease of coverage, and volume of material covered by both the methods. Students were also required to evaluate both methods of instruction. Evaluations of the two methods have also been made by using statistical and other approaches.

Statement of the Problem and Literature Survey:

It has been disturbing to note that a third of the students enrolled for the Engineering Graphics course either dropped out or failed the course for the past several years. This trend in our school need not necessarily represent the national trend. There are several possible causes that attributed to this dismal attrition rate. Some of the possible problems are:

(a) Our need to cover too much material in too short a time.

(b) Many students have inadequate abilities to visualize and form a mental picture.

(c) Lack of interest in the subject.

(d) Lack of aptitude to work on the drawing board.

(e) Many teachers of engineering graphics are not highly skilled in executing sketches rapidly and accurately.

(f) Inability to relate the importance of this course to the practice of engineering.

(g) Inability or lack of interest by many students in putting in the great amount of time required for this course at home.

Application of educational technology to non-engineering courses seems to have proven very successful. If the number of educational articles being published and the educational technology equipment and instructional material being advertised is any measure, then the recent growth of such educational methods must be phenomenal. In this research project, the investigators made use of commercially-available transparencies. Upon purchase, they were integrated into the lectures. A series of lectures alternating blackboard presentations with transparency presentations were made in an effort to evaluate the impact of transparencies. This evaluation of effectiveness was done using several different approaches.

Literature on engineering graphics was surveyed for developing a methodology for this project. It was disappointing to note that very little published research has been done on the use of educational technology in improving engineering graphics instruction. There are studies on the use of educational technology in improving instruction of other engineering courses. Engineering graphics is unique in the sense that no other engineering course demands the mental image forming capabilities of this course. Hence, we were particularly interested in studies related to engineering graphics. The work of C.W. Chance (1) on the use of colored transparencies in engineering graphics instruction was reviewed.

> Teachers of engineering graphics are always searching for methods or materials that can add zip to their classes. The authors share their experiences in using commercially-available transparencies in an attempt to improve their course. In the paper, they carefully describe their methods, the materials they used, and the results they observed.
>
> The writers have acknowledged that the experiment was not well-controlled. Possibly because of this, the results do not show a significant difference between the two teaching methods (with or without the commercial transparencies). One cannot know if a similar conclusion might have been reached using more stringent controls. Nevertheless, important knowledge can be gained from the paper which teachers will find valuable.
>
> - Dr. Larry L. Northup
> Iowa State University

J.H. Earle's (2) work on an experimental comparison of three self-instruction formats for descriptive geometry, though not directly related to our study, was found in existance. As this is another approach for the improvement of instruction, this work was not reviewed. Notwithstanding our disillusionment and disappointment at this apparent dearth of information, it was decided to write to several engineering graphics instructors across the country to find whether any of them could provide us with a lead on published work as well as let us know what they were currently doing in this area.

The directory of the Engineering Design Graphics Division of the American Society of Engineering Education was used to obtain the names and addresses of some leaders in this field. A list of forty-two professors was compiled and a survey letter mailed to each. The letter requested information on the use of audiovisual materials for instruction in engineering grpahics, research which has been conducted or which is currently being conducted. Twenty-one replies were received. Six did not have any information to offer. Five of them gave references to resource material with one giving information on research work by C.W. Chance (1). Twelve of those responding indicated that audiovisual materials are being used to teach engineering graphics. Some apparently give only a few lessons by the audiovisual mode while others teach entire courses. In some cases a format resembling self-paced instruction is used. While perhaps 20% - 25% of the departments may be using audiovisual materials to some extent there does not appear to have been much research designed to evaluate the effectiveness of audiovisual materials for instruction in engineering graphics.

Methodology of the Study

At the outset, brochures and catalogs from different audiovisual instructional material dealers were obtained. Overlay transparencies suitable for the courses were purchased from several companies. A list of these transparencies with the sources and costs appears in the Appendix. Upon receipt of these materials they were reviewed and inconsistencies in notations were removed. A detailed day-to-day instructional plan for lecture instruction was prepared integrating the overlay transparencies bought. Although overlay transparencies were purchased for all the topics taught in the course some of them were not used since lectures were alternated between overlay transparencies and blackboard sketches. This strategy of alternating the method of presentation was required to evaluate the effectiveness of the overlay transparencies in improving instruction and developing the required skills.

At the end of each lecture, the students were required to evaluate both modes of presentation. A statistical analysis of these student evaluations was made in order to determine the student's perceptions of the relative effectiveness of the two methods of instruction.

In a typical engineering graphics course it is expected that topics such as: use and care of drafting instruments, lettering, geometric construction, theory of orthographic graphic projection, orthographic projection of points, lines, planes, simple solids, auxiliary projection, freehand sketching, sectional views, basic dimensioning and production dimensioning are covered. The pre-test was designed covering the above topics to test the prior knowledge of students enrolled in this course. Only a few of the freshmen of this group were exposed to some kind of mechanical drafting either in high schools or on the job before coming to O.D.U. A pre-test was given to determine the drafting knowledge the class brought to the course. This test, as already pointed out, was a very comprehensive one with completion-type questions. A sample of the questions in the pretest given was: "When a visible and an invisible line coincide, the ___________ line takes preference". Also pictures of some solids with multiple views and one/two missing lines were given in the pretest. The post-test administered at the end of the semester was designed to test for the same skills and knowledge as the pre-test. The questions were essentially the same but in a different form. That is, the format was changed from completion to multiple-choicce. A typical question on the post-test was: "In an isometric drawing a circle on the surface of a cube is drawn as (a) A parabola, (b) a hyperbola, (c) a circle, (d) an ellipse." (Readers interested in having a complete set of the pre-test and post-test are encouraged to write to either of the authors.)

Mean difficulty indexes of pre-test and final examinations were compared for questions given from blackboard presentations and transparency material presentations. Ratios of number of course "incompletes" to total number of students enrolled were compared for the past four semesters. To ensure uniformity in grading by different instructors of the lab work and tests, a standard written instruction procedure for grading was developed. This was found to be extremely helpful in grading the lab work and tests.

Analysis and Discussion:

This portion of the report is primarily devoted to a description of different approaches used in evaluating the impact of the use of overlay transparencies in engineering graphics instruction. An extensive search of literature, as pointed out earlier, threw light on only one study that was performed during the early sixties at the University of Texas by Clayton W. Chance (1). There are some major differences between his study and this study at Old Dominion University. The first difference is that his study was performed to evaluate the effect of overlay transparencies in teaching Engineering Descriptive Geometry whereas in our study this subject material constituted only 60% of all material covered. Second, the overlay transparencies were made by the researcher himself in contrast to using commercially available transparencies. Third, lectures with either transparencies or with blackboard sketches were given to a small audience of about 25 compared to an audience of over 100 for the lectures given for our study. Lastly, he had control as well as test groups. For our study the group was exposed to both methods of lecture presentation alternately. The methods of evaluation used in this study are discussed as follows.

a. Opinion of the students: As written elsewhere, the opinion of students were sought at the conclusion of each of the ten lectures presented with overlay transparencies and nine lectures given with blackboard demonstrations. They were particularly required to rate the lecture on the following aspects using four scales; (i) not at all, (ii) a little, (iii) moderately, and (iv) a great deal.

(1) To what extent did the presentation help you to understand the principles discussed?

(2) How much did the presentation aid you in forming a mental image of the physical relationships existing in the problems discussed?

(3) How well did the presentation appear to be organized?

(4) Did the coverage of the material seem to be thorough?

(5) How confident are you that you could solve a new problem involving the same principles as those discussed in the presentation?

The responses were weighted and mean response numbers were obtained for all 10 transparency lectures and nine blackboard lectures. A statistical test at 95% significance level did not indicate any appreciable difference between the two methods. It was thought that the two methods might have some significant effect as perceived by students when tested on the responses obtained for the five questions individually. Ironically, it was found that at 95% significance level student responses did not indicate a significant difference between the two modes of instruction. It has been reported by C.W. Chance (1) that the colored transparencies were found to have helped in improving the performance of the students. The conflicting conclusion drawn in this study based on the students' opinion may not be a true indicator. For one thing, as the students were repeatedly exposed to this rating form, they may have tended to check the responses even without reading the questions. Furthermore, as has been the case previously the students were given some briefing in the laboratory related to the solution of assigned problems. As the end of the semester neared a sizeable number of students started missing the regular lecture which emphasized general principles and depended more on application oriented laboratory lectures to bail them out. This uncontrollable factor contributed to the reduction of the number of filled-out questionnaires returned to the lecture instructor. The comments received from students seem to indicate that the students would prefer a mixture of blackboard and transparency mode of presentation.

b. Comparison of course incompletion ratio: It was indicated earlier that this course has always posed a real threat and challenge to a majority of the engineering and engineering technology students. It may be worth mentioning that more students register for this course a second time than any other course in the engineering school. Therefore, it was assumed that a comparison of ratios of students who did not complete the course to the total number enrolled for the course would probably indicate any significant impact from the use of transparencies. Students who either dropped out or failed the course were included in the category of students who did not complete the course. The faculty have observed that most dropouts are due to the student either falling behind in completing the assigned laboratory work or failure on tests. Often both factors are involved before a student finally decides to give up. The following table gives relevant data and incompletion ratios.

TABLE 1

COURSE INCOMPLETION RATIO

Student Categories	Fall 1975	Spring 1976	Spring 1977	Fall 1977
No. of Drops and Failures	35	43	33	41
No. of Passes	60	55	68	82
Total	95	98	101	123
Incompletion Ratio	37%	44%	33%	33%

From the ratios computed for four semesters, it is hard to tell whether transparencies have really improved the dropout and failure ratio. The very high ratio in the Spring 1976 can be attributed to instructor variability. It is also to be recognized that only 10 lectures out of a total of 28 utilized transparencies. By inference, one might conclude that the effectiveness of instruction was not improved significantly with the use of overlay transparencies in this course.

c. Evaluation based on mean difficulty indexes for the descriptive geometry portion of the course: Difficulty index, a measure of how easy a question is in a test, is used for evaluation in education. This course was about 60% descriptive geometry and the rest basic principles of engineering drawing such as geometrical construction, freehand sketching, oblique drawing and multi-view drawing. It has been observed for several years that our students have difficulty in understanding the concepts of descriptive geometry. Furthermore, approximately one-third of this class has received from one semester to four years of high school mechanical drafting, but had not been exposed to descriptive geometry. The difficulty indexes on the pre-test were strongly influenced by this previous experience. Since a disproportionate number of non-descriptive geometry topics were by chance taught by blackboard sketches, the investigators decided to use only the mean difficulty index of those questions related to descriptive geometry on both pre and post tests to evaluate the impact of the transparencies.

In the post test, there were 12 questions from descriptive geometry and six of them were taught using transparencies and the other six using blackboard illustrations. In the final examination 32 questions appeared from descriptive geometry, 20 of them taught with blackboard illustrations and the rest, 12, with transparency materials. The mean difficulty indexes and the standard deviations computed are shown in the table.

TABLE 2

DIFFICULTY INDEX FOR QUESTIONS

FROM DESCRIPTIVE GEOMETRY

Method of Instruction	Pretest	Final Examination
Blackboard Presentations		
Mean	0.1400	0.6495
Standard Deviation	0.1380	0.2185
Audio-Visual Methods Presentation		
Mean	0.1983	0.6967
Standard Deviation	0.0736	0.2062

It can be inferred from the difficulty index that both modes of instruction showed an improvement in the students' knowledge of the subject. The difference in the mean difficulty index levels between the pretest and final examination for the blackboard presentation is about 0.51 and for the transparency presentation is about 0.50. There does not seem to be any major difference between the blackboard and transparency lectures. Hence, it cannot be said that transparencies helped in comprehending descriptive geometry principles any more than blackboard sketches.

Conclusion:

From the three evaluation methods used and from the experience of the instructors in the use of transparency materials, it can be said that the transparencies have not very significantly effected any improvement in the instruction. This may be in contradiction to the findings of C.W. Chance (1) due to the differences between his study and our study as enunciated earlier. However, it may be concluded that the transparencies do offer the following advantages:

a. Aides the instructor in organizing and presenting the lectures.

b. Affords more time for classroom questions on the subject material covered.

c. Enables the instructor in reviewing the basic steps in problem solving by turning overlays easily and rapidly.

d. Helps to improve the viewing image and to make a more professional presentation.

e. Makes a rapid review possible.

f. The speed of presentation makes it possible for a laboratory instructor to give a quick overview of a lecture.

Benefit-Cost Analysis:

With a view to develop a benefit cost analysis for this project, it was attempted to catalog all the benefits accured with the use of overlay transparencies. The cost was easy to compute and the total cost of this project including renumeration receiver for working on this project by the investigators and the cost of the a/v material bought is about \$3,800. Assuming the transparencies could be used for a period of five years (twice a year) the total number of times the transparencies used were found to be ten times. The benefits that accrued to the students from other evaluations were found to be very negligible. However, for the lecture instructor it was found to be very helpful in organizing and delivering the lecture material efficiently. As reported elsewhere a/v materials also enabled lecture instructor to cover more material in the scheduled class time. It is difficult to assign dollar values for these benefits. Hence, the idea of computing a B/c ratio was given up. However, the authors believe that in light of the advantages enumerated and the small costs involved the advantages gained are worthwhile.

Observations and Recommendations:

(a) Transparencies: Considerable effort was required in an attempt to adapt the purchased transparencies to the text. Changes in notation were required and took a considerable amount of time. Generally, there are two approaches used in teaching engineering graphics. One might be classified as a theoretical approach while the other places emphasis on a mechanical step-by-step "how to" instructional procedure with little or no reference to the theoretical basis. The textbook by Hoelscher (4) and others used for engineering graphics at Old Dominion University places emphasis on principles while the transparencies seem to have been developed with much more of a "how to" approach in mind. To what extent, if any, this difference in approach may have made in the outcome of this study would be difficult to ascertain. In the process of reviewing commercially available film strips and slides, it was observed that a majority of these seem to be made for high school and vocational school students rather than college-level engineering students. If we were given a chance to redo the whole study, we would be inclined to make colored transparencies of our own -- suitable for the course content -- rather than buying commercially available films. Taped instruction along with film slides probably if developed may alleviate the problems posed in the instruction of this course. Alternately, a self-instructional format of taped instruction with film strips/slides may also be another tool of educational technology that can be beneficial.

(b) Observations on students comments: The students comments obtained are not very numerous when considered from the total number of ratings. However, they do seem to support the findings from the statistical analysis of the student evaluations. The students in this class seemed to have some preference for the lecture-blackboard presentations. Some students recommend both. The potential effectiveness of the lecture-transparencies mode of instruction may have been reduced by one or more of the following:

1. Instructor had a tendency to speed up presentation too much.

2. The lecturer believes that the principles of descriptive geometry were not developed as thoroughly when transparencies were used as when blackboard sketches were used. It is the lecturer's impression that the transparency presentation often placed emphasis on the "how to" rather than the "why".

3. The lectures were presented in a two-hundred seat auditorium. The projector can not be moved away from the screen by more than ten feet. Consequently, some students had difficulty in reading the notation on the transparencies.

(c) Methodology: The methodology used in this study was alternate instruction between blackboard and transparencies for a series of lectures. Instead, if a class of over 100 is divided into three groups, one control group, one group receiving instruction only with transparencies with very little blackboard sketches, and the last group with both transparencies and blackboard sketches, it would have been very easy to evaluate the impact of transparencies. Of course, these three groups must be homogenous and comparable groups. It may be necessary to isolate those who have had some mechanical drawing in high school and also the students who are enrolling for the second or third time to make the outcome of the study much more meaningful and realistic.

(d) Other Observations: It is conceded that in an educational research study there are so many variables that can be controlled and so many uncontrollable variables. In this short duration study although every effort was taken to keep all the variables under control there were a few instances when some of the variables simply were uncontrollable. For example, during the progress of the study as mentioned earlier, several different laboratory instructors gave numerous lectures during the assigned lab period. Students approached the lecture instructor during office hours seeking help with problems for which instruction was given earlier in the class with transparencies. Instruction during office hours made extensive use of freehand sketches. Also, some students felt that they did not get adequate time for discussion because the lectures were given for a large class in an auditorium.

In conclusion, this has been a very rewarding and excellent learning experience for the investigators. Regardless of whether transparencies do or do not improve instruction, the course content has been improved. This study has necessitated focusing our attention on the students and course content as never before. Also, the pretest gave us a much clearer knowledge of the background knowledge of our students in engineering graphics. The engineering graphics faculty are now more conscious of potential problem areas in the course.

References

1. C.W. Chance, "Teaching Engineering Graphics with Colored Transparencies - An Evaluation" - The Journal of Engineering Graphics, May 1962, Part I and II.

2. J. H. Earle, "An Experimental Comparison of Three Self-Instruction Formats for Descriptive Geometry" - Unpublished Doctoral Dissertation, Texas A & M University, 1964.

3. Bowker and Lieberman "Engineering Statistics' Prentice-Hall Inc., 1972.

4. Hoelscher, R.P., Springer, C.H., and Dobrovolny, J.S. - "Graphics for Engineering-Visualization, Communication, and Design," John Wiley and Sons Inc., New York 1968.

APPENDIX

List of A/V Materials Purchased:

Description	Amount	Source
Drafting Equipment and Techniques	$116.50	ADG, Inc. 100 Parkdale Rd. Hopkins, Minn. 55343
Freehand Technical Sketching	87.75	"
An isometric Illustration of an Object in Space	7.35	Creative Visuals 879 W. Broad St. Richmond, V. 23220
Top View, Front Elevation & Right Side	7.35	"
A Level Line and the Angle with the Frontal Image	7.35	"
A Frontal Line and Angle with the Horizontal Plane	7.35	"
A Series of Auxiliary Views	7.35	"
True Slope, Bearing and True Length	7.35	"
Three Oblique Intersecting Lines	7.35	"
Three Intersecting Lines	7.35	"
True Slope, True Length and Bearing	7.35	"
Point View of Two Parallel Lines	7.35	"
An Oblique Line and a Profile Line Appearing Parallel	7.35	"
The True Angle Between Two Intersecting Lines	7.35	"
Shortest Distance from a Point to a Line	7.35	"
True Size of an Oblique Plane	7.35	"
True Slope of an Oblique Plane	7.35	"
Angle an Oblique Makes with the Frontal Image Plane	7.35	"
To Determine the Shortest Distance	7.35	"
To Find the Shortest Distance Between Two Nonintersecting	7.35	"
The Shortest and Shortest Level Distance	7.35	"
The Shortest Distance Between Two Non-Parallel	7.35	"
Intersection Between an Oblique Plane Vertical Cutting	7.35	"
To Find the LIne of Intersection	7.35	"
The Line of Intersection Between Two Planes	7.35	"
To Find the Line of Intersection of Any Two Oblique Planes	7.35	"
True Size of the Dihedral Angle by Projection	7.35	"

List of A/V Materials Purchased:

Description	Amount	Source
To Find Where a Line Pierces an Oblique Plane	7.35	Creative Visuals 879 W. Broad St. Richmond, Va. 23220
To Draw a Line Perpendicular to a Plane	7.35	"
Passing a Plane Through a Point	7.35	"
To Find the True Size of the Angle a Line Makes	7.35	"
The True Length of an Oblique Line	7.35	"
Angle Between a Line and Plane Solved by Revolution	7.35	"
Projecting a Circle Upon an Oblique Plane	7.35	"
Orthographic Projection and View Selection	11.00	John L. Glisson, Inc. 819 W. Broad St. Richmond, Va. 23220
" " View Arrangement	6.25	"
Point Projection	8.95	"
Primary Auxiliary Views	10.25	"
Auxiliary Views of Non-Symmetrical Surfaces	11.00	"
Summertrical Surfaces, Cylinders and Irregular Shapes	10.50	"
Completion of Principla Views from Auxiliary View	11.00	"
Secondary Auxiliary Projection	11.00	"
Secondary Auxiliary Views	11.00	"
Revolution-Rotation of Objects	8.95	"
Types of Pictorial Drawing	2.30	"
Oblique Drawing I	5.40	"
Pictorial Drawing Cavalier	6.65	"
Oblique Cylinders	6.05	"
Cabinet Drawing I	4.70	"
Oblique Drawing II	6.05	"
Principles of Isometric Drawing	6.65	"
Isometric and Non-Isometric Lines	5.40	"
Parallel Curves in Isometric	7.55	"
Non-Isometric Curved Lines	8.15	"
Developing an Isometric Circle	8.75	"
Isometric Circles	8.75	"
Locating Isometric Circles at a Given Point	8.15	"
Isometric Arcs and Tangents	6.05	"
Isometric Drawing Cylinders and Arcs	7.55	"
Constructing Isometric Cylinders	6.05	"
Application of Isometric Cylinders	7.55	John L. Glisson, Inc. 819 W. Broad St. Richmond, Va. 23220
Arcs-Non-Isometric Shapes Pully Blocks	8.15	"
Constructing a Non-Isometric Slot	7.55	"
Introduction to Selecting	4.55	"
The Cutting Plane	6.65	"
Three Applications of Full Section	8.75	"
Section Drawing Full Section	6.65	"
Section Drawing Half Section	6.65	"
Offset Section	6.05	"
Revolved Section	6.65	"
Removed Section Hammer Handle	6.65	"
Broken Out Section	6.65	"
Other Types of Sections	5.75	"
Assembly Sectioning	6.65	"
Pictorial Section Drawings	5.15	"
TOTAL:	$750.95	

Jon M. Duff
The Ohio State University

VISUAL PERCEPTION: THE PROBLEM OF CREATING VIRTUAL SPACE

Professor Duff quite eloquently and authoritatively presents some basic concepts dealing with a subject which should be of vital concern to every reader. While one may question whether "many" engineers have possessed the visualization powers demonstrated by Tesla, the issue and facts are nonetheless quite clear. I was a bit disappointed to find no answers to the problem of teaching Visual Perception, but realized the author hadn't offered solutions, just the problems and a great deal of careful thought on which to build. It is now the task of some advocates like author Jon Duff, Bill Vanderwall-or you-to "solve" the "problem" presented....which logically requires mention of an earlier, less profound article on teaching visualization, which appeared in the JOURNAL, Winter 1977, V 41, nl, p 47, and might prove helpful...
Paul S. DeJong, P.E., ed.

Anyone who has studied, taught, or practiced any of the systems of projection employed in the visualization of objects, processes, or design relationships has flirted with a powerful psychological phenomonon. The inability of students to recognize this phenomonon has caused teachers of allied subjects to join in a common lament: that fully 20 percent of drawing students manifest a total inability to "see" the missing third dimension, that 60 percent "see" with only the greatest difficulty, and that only 20 percent are able to actually jump into the drawing, that is, to make full use of the capabilities of the image.

VIRTUAL SPACE

This ability to see is a complex psycho-perceptual relationship which allows the creation of three-dimensional space of no measureable depth. This is called "virtual space" and represents the real experience of psychologically creating some three-dimensional form on a two-dimensional surface. Susanne K. Langer, in her book Feeling and Form,[1] presents an aesthetitian's view of the creation of virtual space. She did not explore the relationship of virtual space and technical visual production, the task which is undertaken here. She also did not explore the instructional or androgogical implications in her conception of the creation of virtual space.

This existence of three dimensions on two-dimensional surface is the paradox of technical drawing and the major limiting force keeping designers, engineers, and technologists from realizing the full potential of the visual image as an active design tool.

The creation of virtual space has its parallels in other fields of creation. Authors subcreate[2] entirely valid secondary worlds which exist as genuinely as the primary world we all live in. Many of the truly gifted engineering scientists have been able to test their inventions mentally, through a form of precognition, before the first drawings were ever made. Nikola Tesla was able to build, run, and inspect his electrical contrivances for wear in a mental process.[3]

VIRTUAL SPACE: THE CORE OF ENGINEERING GRAPHICS

The orthographic system of projection requires the observer to assemble the three-dimensional object from the correlated views through a "reading" process. This unnatural procedure commonly presents problems to those without graphical fluency. Modern systems of descriptive geometry are designed so that complex graphical relationships may be viewed from a unitary viewpoint. Even those with the ability to manipulate such images often demonstrate the inability to see directly in virtual space. They either move around in 90 degree spurts or unfold projection boxes. The fact remains that the virtual spatial relationship existed in the virtual space of the very first projection.

That this virtual space does exist is pointed out by the several texts which have used the device of the 3-D stereo image in order to facilitate its recognition (see inside cover of Fall, 1977 EDGJ as an example). The image viewed through the glasses is the view of virtual space existing conventionally in the orthographic image. A problem exists when a student views the meaningless stereo image without the special glasses, the images being incorrect in virtual space. The teacher's charge is to encourage the student's development of his or her own "orthographic eyes" which assemble virtual space without 3-D devices.

Engineering graphics is but one field which relys on the creation of virtual space. Indeed, each time a mark is made on a two-dimensional surface, virtual space is created. But it is engineering graphics, as opposed to graphic art, graphic design, or fine art, which places exacting and predictable demands on the creation and use of this virtual space.

THE ACT OF CREATION

The point at which technical and fine drawing were cleved marks a critical point in understanding the importance of the act of creating virtual space. Executing an engineering drawing has often been taught as a set of mechanical steps which, if followed systematically, will result in the same product as that produced by one creating virtual space. What is lost in the mechanical creation is the synergistic benefit of the conscious creation of virtual space; the activity which is of true - even aesthetic-value.

The creation of virtual space and the reading of virtual space are not separate activities. Also, the creation of virtual space is not the same as the making of a drawing. Following is the most important concept concerning the creation of virtual space. As you read it, think of the psychological differences between making a drawing (a two-dimensional representation of the object in virtual space) and actually creating the object in virtual space.

> "In virtual space the object is actually constructed; in a drawing an image of the object is represented on a two-dimensional surface."

THE ABILITY TO CREATE VIRTUAL SPACE

There appear to be three distinct groups to consider when attempting to guide the development of this facility in creating virtual space. Each of these groups requires a different androgogy in order to facilitate the greatest use of the image as an active reinforcement of the design process. Each student will develop a different level of expertise, both in seeing virtual space, and in actually creating the form. It is the teacher's charge to guide each student in the development of his or her greatest potential to use virtual space as an active analytical tool.

The three groups which must be considered are:

Group One: These individuals actually construct three-dimensional form on the two-dimensional surface. As a participant in virtual space they are able to mentally junp in and out of the plastic surface. They create virtual space.

Group Two: These individuals create the representation of three-dimensional form on the two-dimensional surface. They tell themselves that they are creating virtual space, but they are actually visual mechanics. Their drawings may be outwardly identical to the view of objects created in virtual space by Group One, but are not for them, the same. The images are symbolic of the objects in virtual space.

Group Three: These individuals see the symbols of objects in virtual space as flat, two-dimensional diagrams. The representational image is lost and the drawing takes on the visual vitality of a tic-tac-toe diagram.

Fully 20 percent of the general population fall into Group Three, 60 percent in Group Two, and 20 percent in Group One. Ideally engineers, engineering technologists, designers, and architects should fall into Group One. But as is often found; they don't, they won't, or they can't.

The idea of creating virtual space, as opposed to pushing a bunch of lines around on a two-dimensional surface, is not a new one. Every teacher of graphics has experienced virtual space to some degree. The preceeding discussion raises the following questions which concern students, practitioners, and teachers of graphics.

1. Can the ability to create virtual space be developed in every graphics student?

2. Should the ability to create virtual space be developed in every graphics student?

3. If virtual space is in fact created, what is its relationship to the solving of visual problems?

4. What is the androgogy which results in the development of graphical fluency to the point where the creation of virtual space becomes a casual part of the design process?

5. What is the relationship of creating virtual space to other acts of creation in engineering design such as mathematical modeling, simulation, and conceptual systems design?

Addressing these questions, especially in the context of the definition of the population into the three working groups, will assist in making virtual space more accessable to more individuals.

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Robert P. Kelso
Louisiana Tech University

A NEW ORTHOGRAPHIC MODEL

In an effort to help students (and myself) visualize multiple successive Auxiliary views the orthographic model described below was devised. It is presented here as if it were being presented to students.

....(See Figure 1). If we now take our apparatus to the glass sphere (with the object inside) and affix one of our spikes to the north pole of the sphere and the other spike to some place on the equator and then look down through our flat pane at the top we will see the Top View of our object just as we would if we had the old glass box, and if we then look through the flat plane at the equator we will have a view which we can call our Front View just as we would if we had our glass box. Then if we disconnect the spike from the north pole only and pivot it around so that it too is attached at the equator (making both spikes on the equator, but at different points on the equator) and again proceed to look through our flat planes we will see what will correspond to a Front and Side View as if we had our old glass box.

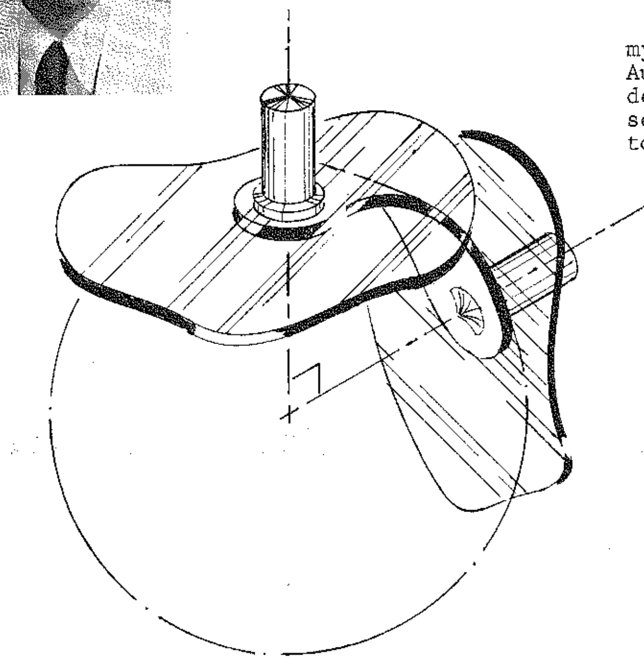


FIGURE I

Where we detached the spike from the north pole above, if, instead of swinging it around to the equator, we had stopped at some intermediate point on the sphere, then looking through the flat pane we would see what corresponds to a First Auxiliary View - and of course, since we did not move our other spike from the equator, a view through its pane would still represent a Front View. If we now leave our spike at the new-found intermediate point and disconnect the one at the equator and pivot it around to any convenient point on the sphere we will have what will correspond to a Second Auxiliary View when we look through the flat pane. This process may be continued ad infinitum, disconnecting one end, pivoting it around, disconnecting the other end, etc., creating an infinite number of auxiliary views, a new one with each new location of the tim. And where principal panes and added auxiliary panes serve as reference planes with the old glass box, our reference planes will now be served alternately by the two flat panes attached to our rim.

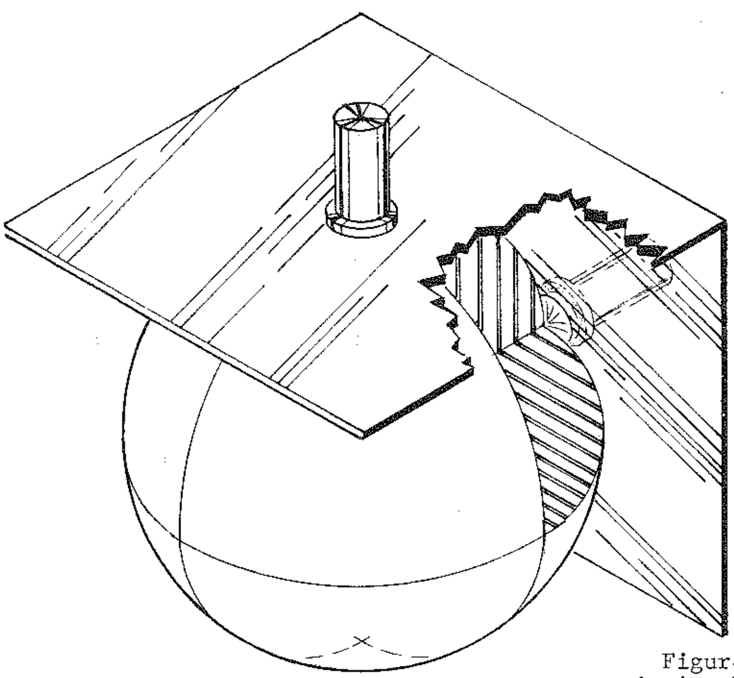
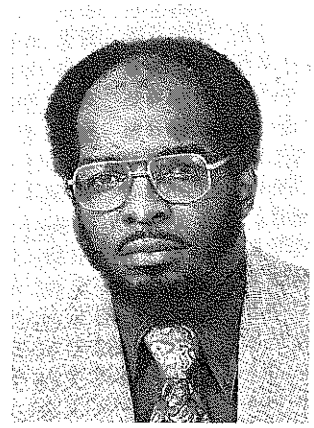


FIGURE 2

Figure 2 is a modification that has merit in that the orthogonal nature of the apparatus is more apparent and the folding line is seen, but I personally do not prefer it because it "feels" clumsy as I mentally step it around the sphere.

Lyndon O. Barton
Mechanical Engineer,
E.I. duPont de Nemours & Co.
Instructor, Delaware Technical & Community College



THE ACCELERATION POLYGON - - A GENERALIZED PROCEDURE

The acceleration polygon method is probably the fastest and most common among the graphical methods employed in solving problems in Mechanisms. Yet for most beginners - students in particular - the construction of the polygon itself can be a puzzling exercise.

To simplify this problem, the following generalized procedure has been developed. This procedure is best described by considering the four-bar linkage mechanism ABCD shown in Figure 1a, where the driven member AB has a clockwise angular velocity, ω_{AB}, and a counterclockwise angular acceleration, α_{AB}. It is required to find the acceleration of point C, a_C.

PROCEDURE

1. Determine the velocities of all points on the mechanism including those with combined motion. This may be done using the instant center method, the effective component method, or as in the present case the relative velocity method.

2. Define a starting point o', called the polar origin. All absolute acceleration vectors originate from the polar origin. By absolute acceleration, we mean the real or true acceleration of the point as observed from a fixed frame of reference such as the earth.

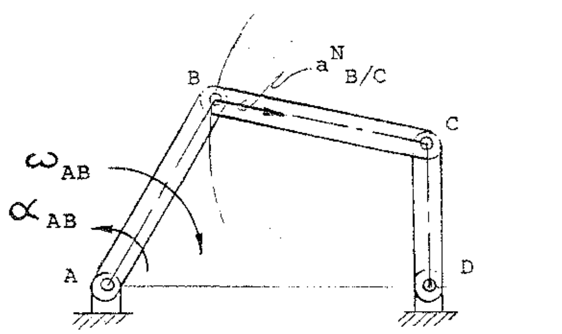


FIGURE 1a - FOUR-BAR MECHANISM

3. Lay out known components of absolute acceleration of the drive member starting with the normal acceleration $a^N_B = AB \times \omega^2_{AB}$ parallel to AB, then adding the tangential acceleration ($a^T_B = AB \times \alpha_{AB}$) perpendicular to it ($a^N_B \perp a^T_B$). The summation of these two components defines the absolute acceleration of point B ($a_B = a^N_B + a^T_B$). If an angular acceleration α_{AB} is not given, then a^T_B does not exist, and a^N_B becomes the absolute acceleration of point B. Define terminus of a_B as b'. It is important to use a lower case letter for clarity.

4. Select another point on the mechanism

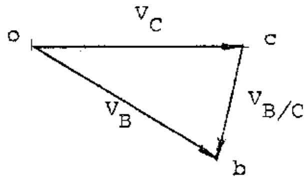


FIGURE 1b - VELOCITY POLYGON -- STEP 1

that has absolute motion and is rigidly connected to point B, namely point C, and layout its normal acceleration component ($a^N_C = V^2_{C/D}/CD$) parallel to link CD. Normal components of acceleration are readily determined from the velocity data and the link orientation.

5. Through the terminus of vector a^N_C, construct a perpendicular to represent the corresponding tangential acceleration (a^T_C) whose direction is known, but whose magnitude is as yet undefined. <u>This line contains the point c', the terminus of acceleration of point C, a_C.</u>

6. To completely define the tangential acceleration a^T_C, we must seek to <u>relate</u> point C, whose acceleration is only partially known, to point B, whose acceleration is completely known. To do this, we consider the connecting link BC and the acceleration of B relative to C

$$(a_{B/C} = a^N_{B/C} + a^T_{B/C}).$$

Lay out vector $a^N_{B/C} = V^2_{B/C}/BC$, and observe the following:

- The direction of this vector is obtained by assuming that point C on the link is fixed while point B rotates about it. In this case $a^N_{B/C}$ lies on the link and is directed toward the center of rotation assumed.

- In accordance with the Polygon Convention, relative acceleration vectors normally <u>do not</u> originate at the pole (o'), but <u>extend</u> between the termini of the absolute acceleration vectors to which they relate. For example:

  $a_{B/C}$ means that <u>polygon vector</u> goes from c' to b', and

  $a_{C/B}$ means that polygon vector goes from b' to c', where b' and c' are the termini of absolute vectors on the acceleration polygon, and B and C are the corresponding points in the linkage.

7. Through the terminus of $a^N_{B/C}$, construct a perpendicular to represent the correspond-

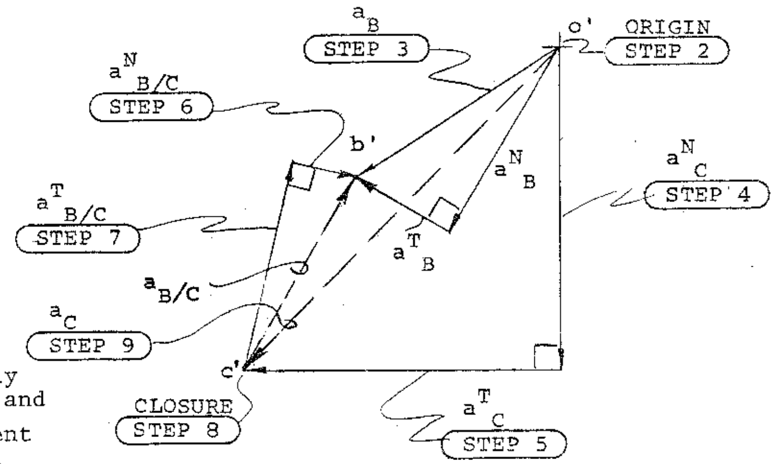


FIGURE 1c - ACCELERATION POLYGON

ing acceleration $a^T_{B/C}$ whose direction is known, but whose magnitude is yet to be determined. <u>This line also contains the point c', the terminus of a_C.</u>

8. Now since c' lies on both $a^T_{B/C}$ (Step 7) and a^T_C (Step 5), it follows that the intersection of these two lines will define that point. Therefore extend a^T_C until they intersect and label the point of intersection c' (use lower case).

9. Finally, lay out the vector from origin o' to terminus c' to define the required absolute acceleration a_C and a vector from terminus c' to point b' to define the relative acceleration $a_{B/C}$.

A quick check of the completed polygon should reveal the balanced vector equation

$$a_B = a_C + a_{B/C}$$

<u>SPECIAL CASES</u>

SLIDER-CRANK MECHANISM

The slider-crank mechanism shown in Figure 2a may be considered a special case of the four-bar linkage mechanism where, in Step 4, the normal acceleration of the slider C (a^N_C) has zero length since its radius of rotation is infinite. Thus the tangential component of acceleration (a^T_C) originates from o' and becomes the absolute acceleration of C (or a_C).

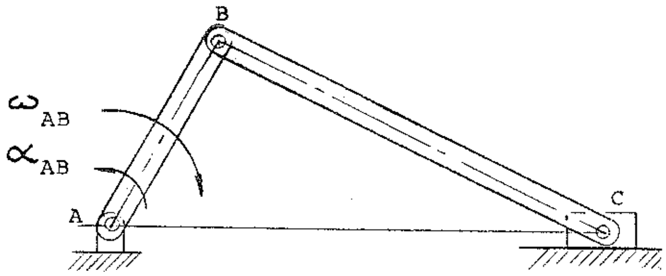


FIGURE 2a - SLIDER CRANK MECHANISM

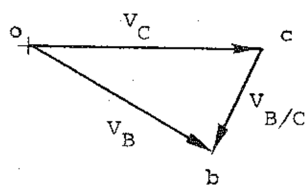


FIGURE 2b - VELOCITY POLYGON -- STEP 1

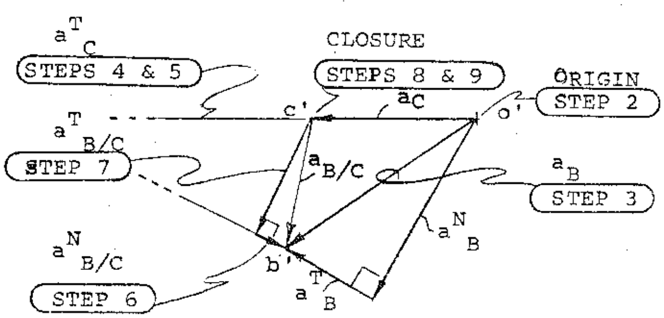


FIGURE 2c - ACCELERATION POLYGON

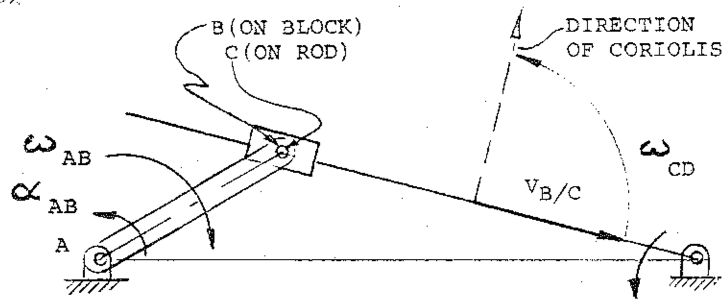


FIGURE 3a - QUICK-RETURN MECHANISM

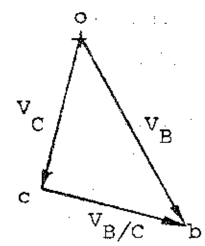


FIGURE 3b - VELOCITY POLYGON -- STEP 1

QUICK-RETURN MECHANISM

Another special case is the quick-return mechanism shown in Figure 3a. Here point B slides on link CD and is coincident with point C. There is no connecting link between B and C, and hence no normal acceleration. Instead we determine the Coriolis acceleration ($a_{COR} = 2V_B^{AB}/V_C^{CD}\ \omega_{CD}$ OR $2V_{B/C}\ \omega_{CD}$) where $V_{B/C}$ and ω_{CD} are obtained from the velocity data in Figure 3b.

<u>For Coriolis acceleration, we always consider the linear velocity of the slider with respect to that of the rotating body and the angular velocity of the link on which the sliding occurs.</u> That is, $V_{B/C}$ <u>not</u> $V_{C/B}$, and ω_{CD} <u>not</u> ω_{AB}).

Accordingly, in Step 6, connect $2V_{B/C}\ \omega_{CD}$ to terminus b' in the conventional manner observing the following:

That this vector has the orientation of $V_{B/C}$ when rotated 90° about its tail in the direction of ω_{CD} (counterclockwise in this case).

That since point <u>B relative to point C</u> on the link is being considered, the polygon vector must <u>go from c' to b'</u> (<u>reverse letter sequence</u>).

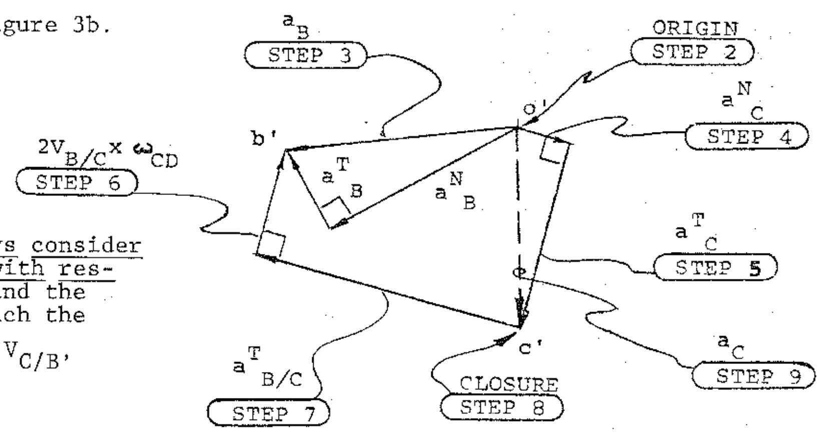


FIGURE 3c - ACCELERATION POLYGON

NUMERICAL EXAMPLE (See Figure 4)

Let AB = 1.5 in., BC = 1.5 in., CD = 1 in., ω_{AB} = 1 rad./sec (CW), and

α_{AB} = 0.5 rad./sec^2(CCW).

Problem: Determine a_C.

SOLUTION

Step 1 Determine the velocities

$V_B = AB \times \omega_{AB} = 1.5 \times 1 = 1.5$ in./sec

$V_C = 1.45$ in./sec (from Figure 2b)

$V_{B/C} = 0.8$ in./sec (from Figure 2b)

Step 2 Define polar origin

Step 3 Determine acceleration of drive point

$a^N_B = AB \times \omega^2_{AB} = 1.5 \times 1^2 = 1.5$ in./sec^2

$a^T_B = AB \times \alpha_{AB} = 1.5 \times 0.5 = 0.75$ in./sec^2

$a_B = a^N_B + a^T_B$

Step 4 Determine normal acceleration of point directly connected to drive point

$a^N_C = \frac{V^2_C}{CD} = 1.45^2/1.0 = 2.13$ in./sec^2

Step 5 Add tangential acceleration (undefined length)

$a^T_C \perp a^N_C$

Step 6 Determine relative normal acceleration between drive point and related point

$a^N_{B/C} = V^2_{B/C} / BC = 0.8^2/1.5 = 0.426$ in./sec^2

Step 7 Add relative tangential acceleration (undefined length)

$a^T_{B/C} \perp a^N_{B/C}$

Step 8 Close polygon and define tangential accelerations in Steps 5 and 7

a^T_C intersects $a^T_{B/C}$ at c'

Step 9 Determine required acceleration

$a_C = a^N_C + a^T_C = 3.2$ in./sec^2

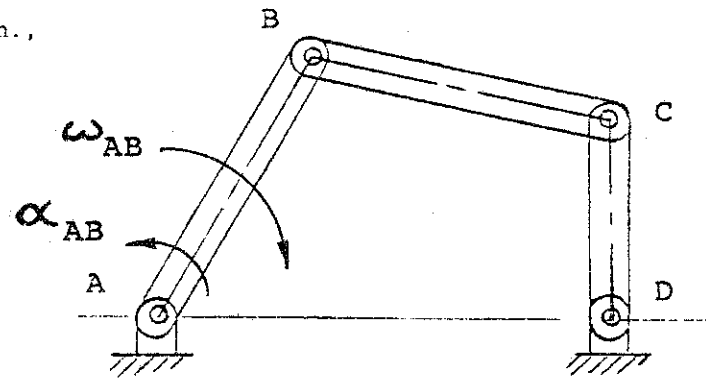
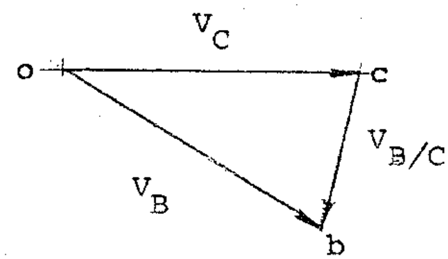
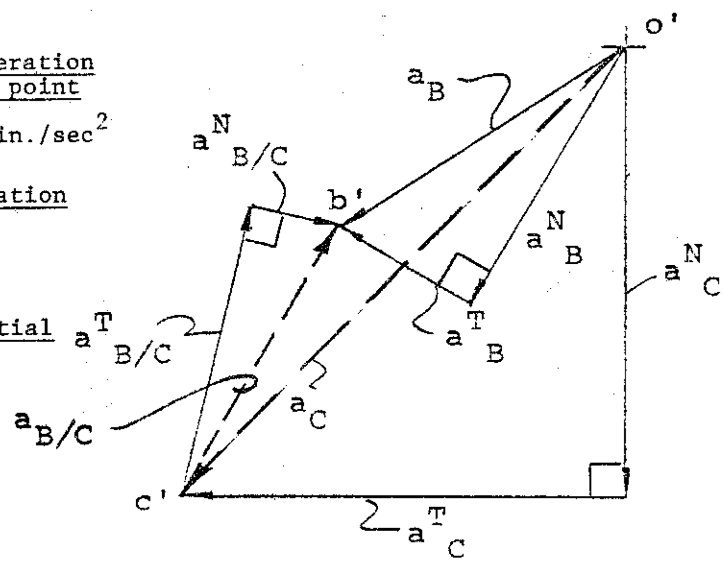


FIGURE 4a - FOUR-BAR MECHANISM



Scale: 1 in = 1 in/sec

FIGURE 4b - VELOCITY POLYGON



Scale: 1 in = 1 in/sec^2

FIGURE 4c - ACCELERATION POLYGON

SUMMARY

The generalized procedure outlined above may be summarized as follows:

1. Proceed from the "known" to the "unknown". That is,

   (a) Lay out absolute vectors whose magnitude and direction are known.

   (b) Lay out components of absolute and relative vectors that are known (magnitude and direction) or can be determined. These include normal accelerations and Coriolis acceleration.

   (c) Add to the components in (b) their corresponding tangential accelerations (directions only), and extend these to close the polygon.

2. All absolute vectors on the acceleration polygon originate from the pole o', while relative vectors extend between the termini of the absolute vectors.

3. (a) A vector that originates from b' and terminates at c' represents the relative acceleration of point C to that of point B on the link.

   (b) The choice between $a_{B/C}$ and $a_{C/B}$ makes no difference in the polygon configuration or the results, except that these vectors have opposite senses.

4. Two undefined vectors such as $a^T_{B/C}$ and a^T_C will contain the point c' on the polygon, and will define that point where they intersect.

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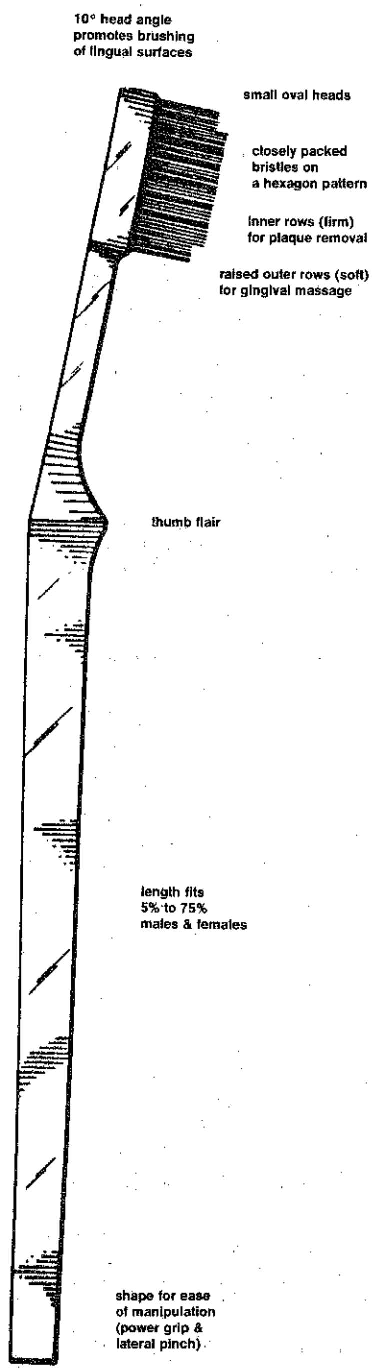
Look what design has done for the toothbrush

What makes the new Reach toothbrush design different from others? It's the fact that from the shape and length of the handle to the toothbrush head, human factors were the main concern.



By J. Roger Guilfoyle

There are few products in such general use as the toothbrush. Almost everyone brushes with some regularity, and children, from an early age, are instructed that brushing helps prevent cavities and maintains healthy gums.

Nonetheless, despite frequent exhortations from dentists that proper brushing is essential to a healthy mouth, people persist in being sloppy about their dental hygiene. In fact, it's estimated that the average person spends only about 65 seconds at each teeth brushing.

Although the earliest mention of tooth-cleaning implements is found in Chinese records of the 17th century, the toothbrush as we know it is the creation of William Addis. Addis, an Englishman, designed the first toothbrush in 1780. Addis' toothbrush had a bone shaft and natural bristles. The bristles were drawn through holes bored in the head of the bone shaft and were secured by wire.

The first American toothbrush wasn't patented until 1857, but since then American ingenuity has more than compensated for the slow start. Today, there are hundreds of patents covering various aspects of manual and mechanical brush design and operation.

One of the more significant developments in modern toothbrush design occurred in the 1930's at a DuPont plant in Leominster, Massachusetts. It was there that nylon monofilament was first substituted for hog bristles. This development substantially increased DuPont's product volume.

In an effort to make another such quantum leap, DuPont approached the Applied Ergonomics Corporation of Westwood, Massachusetts, in 1972. Two of the principals in this company, Percy Hill and John Kreifeldt, are also professors in Tufts University's department of engineering design. A third, Louis Calisti, is a dentist.

DuPont's objective was simple. It wanted to increase sales of its nylon and plastics products, so it asked Hill and Kreifeldt to design an improved manual toothbrush. Among DuPont's requirements were that the toothbrush outperform competitive products and that it be commercially practical.

DuPont came to us," Hill recalls, "because of some work we had previously done on dental equipment. Someone at DuPont had seen a report on a study we made about ways to improve the efficiency of the dentist's office work station. That's why they contacted us."

Hill points out that though the problems involved with the dentist's work station were quite different from designing a toothbrush, DuPont had nevertheless been impressed with the painstaking methodology Applied Ergonomics used in its previous research projects.

Applied Ergonomics started on the project by reviewing existing information on the design of tooth-cleaning devices—especially their comparative effectiveness in protecting dental surfaces from materials that cause cavities and other tooth problems.

Human factors not used

From this research, Applied Ergonomics selected more than 65 articles and studies and 115 patents for intensive study. These patents covered such areas as bristle configurations, handles and grips. "Significantly," Kreifeldt says, "we found no human factors research on toothbrushes in any of the material we reviewed."

At this stage in their research, it became apparent to the design team that plaque removal was the primary objective, with gingival (gum) massage second. "We came to this conclusion, says Hill, "as a result of our literature search and from a series of consultations we had with dentists."

The consensus of the dentists was that the most important consideration in improving toothbrush design was to develop a model that would provide better plaque removal.

The design team then began a study of the public's dental care habits and attitudes by means of a questionnaire distributed to 300 adults. Purpose of the survey was to determine individual brushing habits and to learn what the respondent's regarded as their main tooth problems.

Based on the questionnaire results, the design team made a detailed drawing of the mouth to show which areas were the most difficult to brush. The drawing also showed the directions the average person brushed various dental areas.

"This kind of information," says Kreifeldt, "helps the designer focus on the basic problems. For example, the drawing made it obvious that a toothbrush that would make it easier to brush the inside surfaces of the back teeth would be unquestionably desirable. The designers also found that ease of brushing is a critical consideration. Research showed that the more difficulty a person has in brushing, the greater the plaque build-up the individual will have.

What's best in a toothbrush?

Says Hill, "From respondents to our questionnaire we also learned that the toothbrush with the greatest appeal is one that is a comfortable size; has a full brush-head of white, level bristles; and a plain, simple handle." In addition, the questionnaire indicated that a firm brush is preferred. However, in their research the design team found that persons who use hard bristles frequently damage their tooth enamel and also are more likely to suffer gum trauma.

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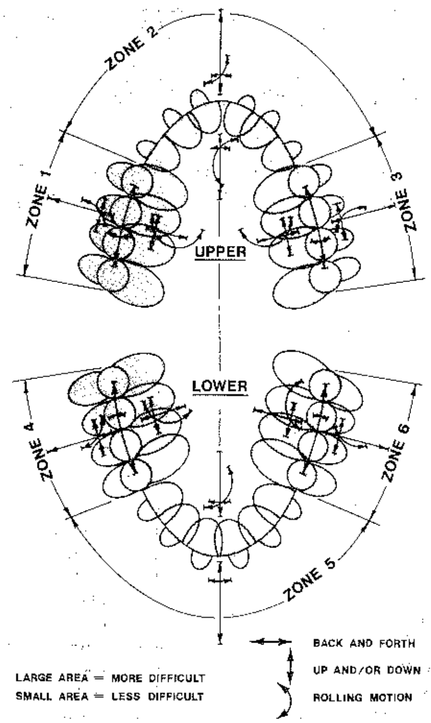


Diagram shows the mouth of an average person distorted to reflect the direction of brushing each area and the difficulty of brushing different areas. Information was obtained from a questionnaire distributed to 300 adults to determine brushing habits.

After analyzing the results of the questionnaire, the design team made comparisons of the forms of many toothbrushes. Says Kreifeldt: "We compared the length and width of the head and handle and the weight of the toothbrush. We also compared other features such as bristles, and then grouped the toothbrushes according to their various features and their price."

At the same time, the designers obtained detailed measurements of hands, teeth and mouths. With this information, they were able to evaluate the geometry of existing brushes and to set physical specifications for the toothbrush they were developing.

After approximately eight months of research, however, the design team found it still needed additional information. "It was clear," says Hill, "that we had to get more facts about how users handle a toothbrush, and the relationship of the toothbrush to the specific dental areas."

Consequently, the design team made a series of time-motion studies to obtain details on the way people brush their teeth. They studied how much time people devote to brushing different mouth areas and the stroke direction they use. They also examined the way people manipulate the brush.

As a result of the time-motion studies, Kreifeldt says, "We discovered that virtually all the subjects rotated their grip on the brush handle. Furthermore, half of them also changed their grip position on the handle."

This information convinced the design team that a contoured grip was undesirable because it hindered hand movements. And, since they had identified a need to resist rotational and linear manipulative forces, they knew that round handles would not be a satisfactory human factor design.

In addition, round handles presented another problem: the diameter of the handle would have to be small enough to fit into the standard bathroom toothbrush holder. Meeting this requirement, the designers found, would make the toothbrush handle too weak.

"Based on our information about brushing direction and the correlation of the toothbrush to the hand," says Hill, "We realized that the conventional 'popsicle stick' handle was not the best design solution—that the handle should be more rectangular, particularly at the forward end, to produce the 'ease of manipulation' requested by questionnaire respondents."

To further validate their toothbrushing studies, the design team had hidden observers, using one-way, see-through mirrors, watch project subjects brush their teeth. The designers also made studies of plaque removal and the effects of brushing time and bristle diameter on plaque removal from the buccal (outside), lingual (inside), and mesial-distal (between) surfaces of the teeth.

In these studies, subjects were asked to brush their teeth for a total of 130 seconds. The subjects' plaque was scored prior to the first brushing and then after each successive 32.5 second interval. The designers used four different bristle diameters in these tests and two different tuft densities. The test brushes with 55 tufts had bristles that measured .006 inch and .011 inch.

The tests showed that brushes with bristles .011 inch in diameter removed plaque the best. The ones with .006 inch bristles proved to be the least satisfactory.

In addition to the information gained about bristle diameter, the plaque-removal studies also demonstrated that there was considerable room for other improvements. "We found, for example," says Kreifeldt, "that only 50 percent of the initial plaque is removed in the normal 65-second brushing time.

Work up prototypes

Using information from the questionnaire, the time-motion and plaque-removal studies, the designers drew up a list of specifications. These specifications led to development of two prototypes.

"Each of the prototypes," Hill says, "had individual characteristics which required testing. For example, one prototype had a bilevel bristle-head, with soft outer bristles and firm inner bristles."

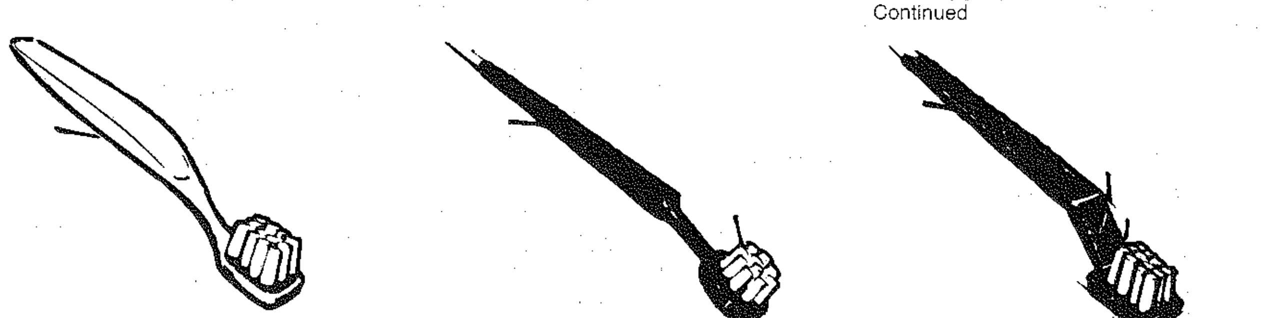
The firmness of the inner bristles was achieved partially by using a wider bristle and partially by extra dense packing of the bristles. The extra density of the bristles was made possible by using a hexagonal rather than a linear hole arrangement.

"What we found," says Hill, "was that the firm feeling, desired by many users, can be achieved without using hard bristles which often cause tissue trauma." This prototype had a slightly rounded handle that tapered toward the bottom end.

The alternative prototype had bristles of the same diameter, but slightly shorter in length. According to Hill, shorter bristles increase the feeling of firmness. The handle of this prototype was also tapered toward the bottom, but it was trapezoidal in cross-section. Both designs were produced in sufficient quantities to test their effectiveness in plaque removal and also to measure consumer acceptance to the new product.

The prototype toothbrushes were then evaluated against two other commercially available toothbrushes. Test results showed that both prototypes were superior to the others in removing plaque.

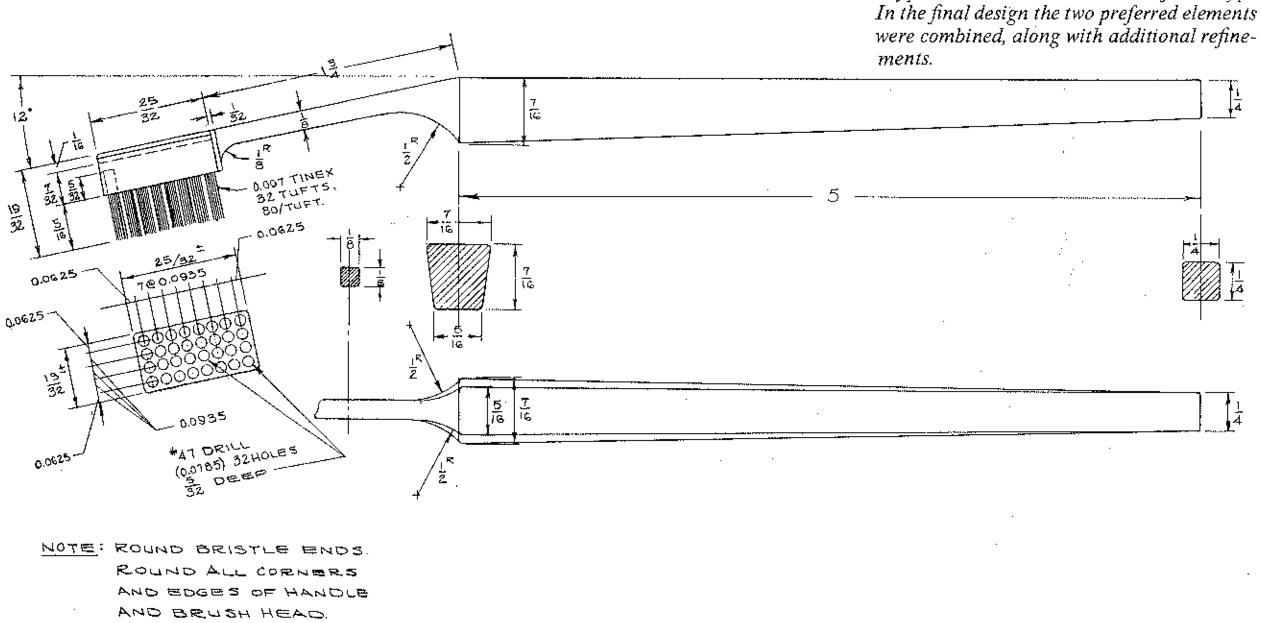
Continued

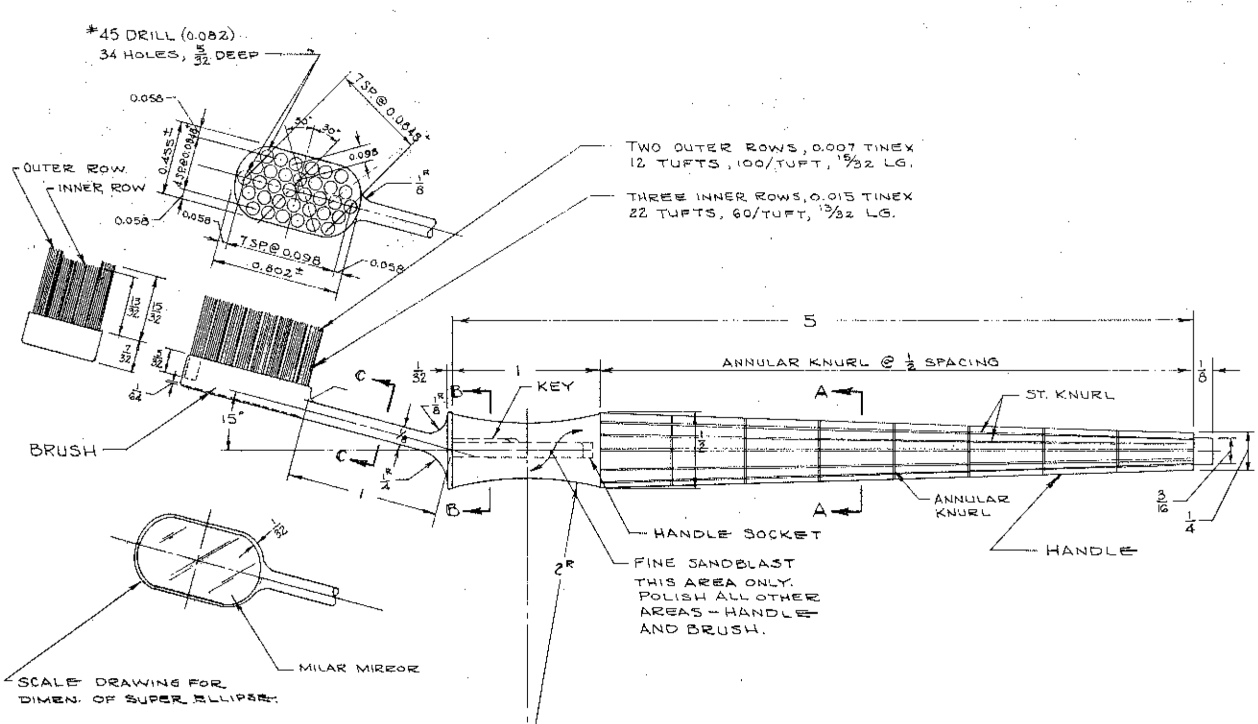


Sketches of various early stage design concepts.

What design has done for the toothbrush

Two prototype designs selected for testing. Study results indicated a preference of the head of Prototype A, bottom, and the handle of Prototype C. In the final design the two preferred elements were combined, along with additional refinements.



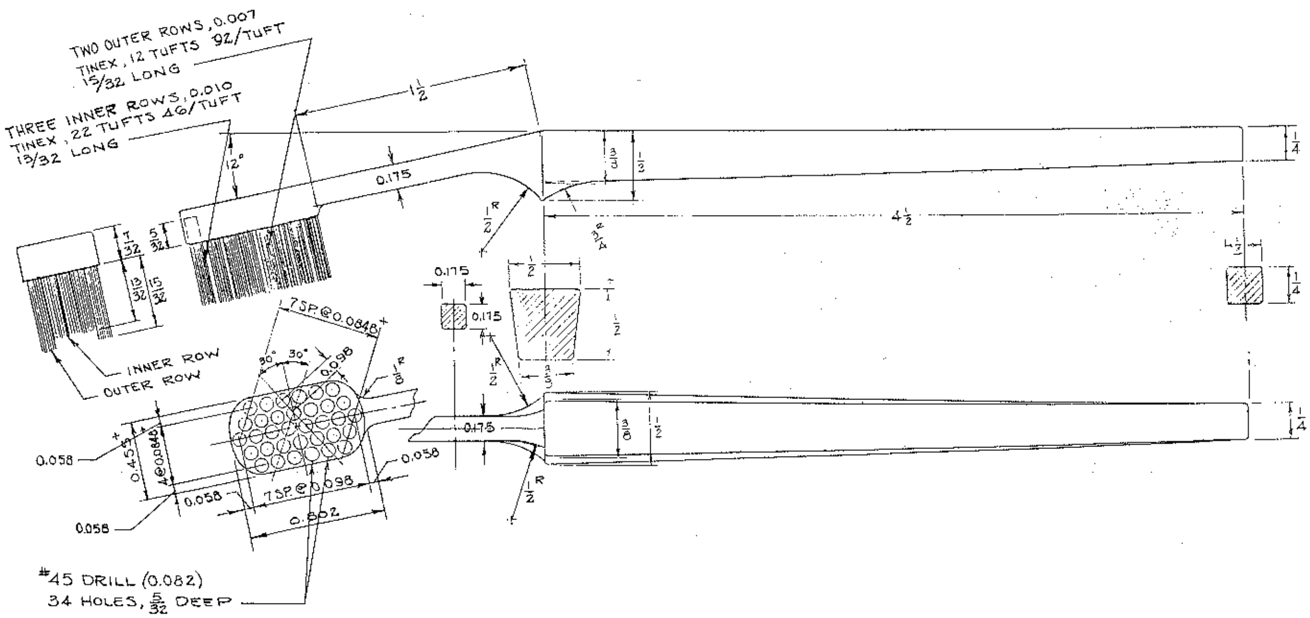


This article is a discussion of work done by two well-known members of the division, Percy Hill and John Kreifeldt, both of Tufts University and principals in Applied Ergonomics Corp. Many of our teaching and practicing creative design and related courses should find a lot of "case study" material here for class discussion. There are also interesting and unusual drawings that demonstrate effectively the importance of comolete details and dimensioning.

We want to take this opportunity to thank Mr. George Finley, editor of INDUSTRIAL DESIGN, for permission to use the article.

- P.S. DeJong

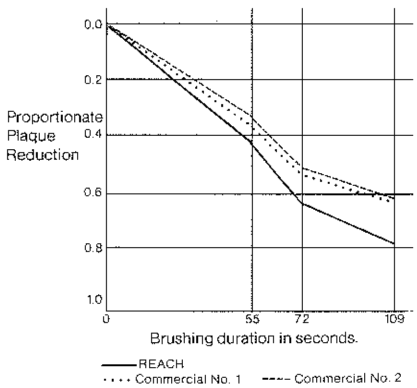
Materials and components:
Brush handle: Injection molded and drilled nylon.
Bristles: DuPont Tynex stranded nylon filaments.



Final toothbrush design combining Prototype A and C concepts (left).

Proportionate plaque reduction scores for three test toothbrushes

Total Surface plaque
(Mesial-distal, buccal and lingual areas)



Following are the results of typical clinical study of the Reach toothbrush as compared with other commercial toothbrushes.

Objective findings, Clinical Study No. 2: 447-patient study. Reach vs 2 other brushes, all with dentifrice.

Patient composition: *149 subjects in each of three test groups, testing the Reach brush against two leading commercial brushes. Subjects' ages were between 17 and 70. All individuals tested employed their normal brushing techniques. Unlike the previous clinical study, subjects were allowed free use of a major dentifrice. (The same brand of dentifrice was used by all subjects.)*

Objective: *To determine the comparative effectiveness of the three test brushes on dental plaque deposits.*

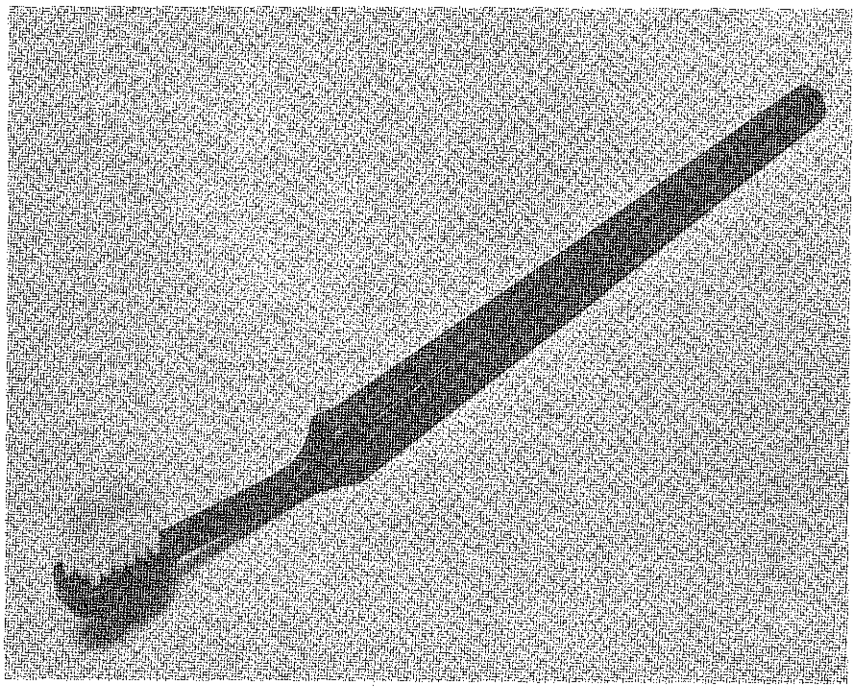
Methodology: *Based on a cumulative removal of plaque evaluated at three selected intervals; total brushing duration of 109 seconds, i.e., subject brushes for 55 seconds, then for 17 seconds, then for 37 seconds. Brushing times were determined by actual in-home monitoring of 132 use-test participants.*

Brushes were issued in a random order unknown to either the hygienist-scorers or the individuals recording the plaque scores. Each of the 447 brushes had been assigned a code number, entered on a scoring sheet for later identification. All scoring and procedural details were identical to the earlier dentifrice-free test.

Conclusions:

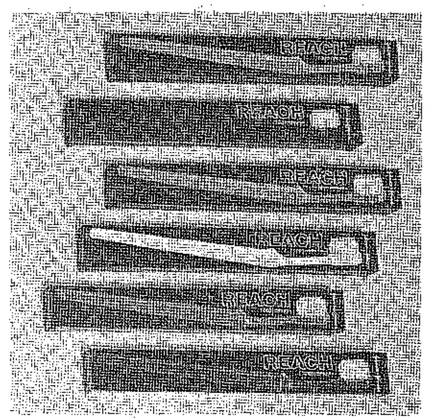
Both in total plaque removal and in gingival plaque removal, the Reach brush removed significantly more plaque than the two brushes of standard design, regardless of surface or zone. A high magnitude of consistent effectiveness: The degree of effectiveness of the Reach brush in removal of gingival and total plaque increased proportionately with the length of brushing time. However, regardless of the brushing time period, the area of the mouth, or type of plaque involved, the Reach brush was found consistently more effective in plaque removal compared with the two standard-design brushes.

What design has done for the toothbrush



Left
The final product featuring all the carefully worked out human factors toothbrush innovations.

Below
Package for the Reach toothbrush is designed to best display the human factors design that went into the final product.



Credits:
Project: The Reach Toothbrush for E.I. DuPont de Nemours & Co., Inc., Fabrics and Finishes Department, Wilmington, DE.
Design Consultant: Applied Ergonomics Corporation, Westwood, ME. Percy H. Hill, president, John G. Kreitfeldt, Ph.D, Louis P. Calisti, D.M.D., dental consultant.
Client staff: Andrew F. Rutkiewec, Dominic P. DuIulio, J.M. Jankowski.
Manufacturer: Johnson & Johnson, New Brunswick, NJ.

Interviews with users indicated a preference for the head of the bilevel prototype and the trapezoidal handle of the other. As a result, the designers blended the best features of the two prototypes into a new product, called the Reach toothbrush (trademarked name).

The Reach toothbrush has tightly packed bilevel bristles arranged hexagonally. The raised outer rows of .007-inch diameter bristles provide gingival cleaning. The inner bristles, .010-inch in diameter, are designed for plaque removal.

Reach has a slender, elongated neck that joins the head to the handle. According to the designers, this neck makes it easier to get at hard-to-brush areas, particularly the back teeth.

The Reach toothbrush has the smallest and most compact brush head on the market. Studies show that it suits adult mouths of all types, regardless of dental arch variations. As Hill points out, "The small toothbrush head makes the user concentrate more on brushing. The user does two teeth at a time, not four or five."

The Reach toothbrush's angled, shaped handle is designed to provide a comfortable grip and to be easy to manipulate. A further refinement is the contoured area for the thumb at the joint of the handle or neck which makes brushing easier.

Get client support

As Hill recalls the history of the development of the toothbrush, "DuPont was extremely supportive throughout all the development phases. At one point, when we were insisting that the holes in the toothbrush head had to be drilled tightly and hexagonally, and the DuPont engineers in Leominster (Massachusetts), were saying it couldn't be done, DuPont's management backed us up. They said, 'if you can't produce it this way, then we will take the project to someone who can.' "

Reach was introduced nationwide last fall by Johnson & Johnson, which acquired the rights to the product from DuPont earlier this year. J&J is sanguine about Reach's market potential. "The Reach toothbrush is not just another toothbrush," says Richard Czerniawski, "but a major innovation in home dental care." Czerniawski is the Reach product director at Johnson & Johnson.

Describing the company's plans for promoting the product, Czerniawski says, "Reach's marketing program will include year-round TV advertising and professional, trade and consumer promotions. This is the first for home dental products." ID

Ming H. Land
Miami University

APPLICATION OF ODAKA'S EQUATIONS FOR PERSPECTIVE PROJECTION TO THE DETERMINATION OF SCALES AND ELLIPSE GUIDES IN AXONOMETRIC DRAWING

INTRODUCTION

In three-point perspective, the object is placed so that none of its principal edges are parallel to the picture plane (PP); therefore, each of the three sets of parallel edges will have a separate vanishing point (VP). As an illustration, the three-point perspective of a cube is shown in Figure 1. The three front edges, OD, OE, and OF, meeting at O, are located along the converging lines from O to the three vanishing points, A, B, and C. Let $\angle BOC = \alpha$, $\angle COA = \beta$, and $\angle AOB = \gamma$. Odaka's (1978) equations describe the three-point perspective of a cube in the three equations (1) shown in the box below,

where $a = OA$, $b = OB$, $c = OC$, $d = OD$, $e = OE$, $f = OF$.

These are Odaka's equations of perspective projection from which equations for other types of pictorial projection can be derived.

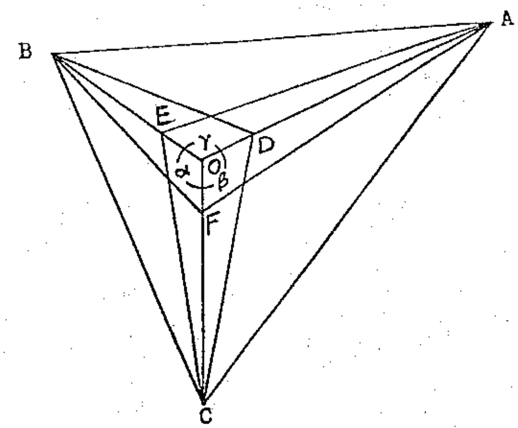


Figure 1

$$\left.\begin{aligned}
\frac{a^2 - c\cdot a\cdot\cos\beta - a\cdot b\cdot\cos\gamma + b\cdot c\cdot\cos\alpha}{b^2 - a\cdot b\cdot\cos\gamma - b\cdot c\cdot\cos\alpha + c\cdot a\cdot\cos\beta} &= \left(\frac{e}{d}\cdot\frac{a-d}{b-e}\right)^2 .\\
\frac{b^2 - a\cdot b\cdot\cos\gamma - b\cdot c\cdot\cos\alpha + c\cdot a\cdot\cos\beta}{c^2 - b\cdot c\cdot\cos\alpha - c\cdot a\cdot\cos\beta + a\cdot b\cdot\cos\gamma} &= \left(\frac{f}{e}\cdot\frac{b-e}{c-f}\right)^2\\
\alpha + \beta + \gamma &= 4\,R\angle .
\end{aligned}\right\}\quad\cdots\cdots\cdots\cdots(1)$$

For axonometric drawing, since

$a \cdot \cos \beta = b \cdot \cos \alpha$,

and $b \cdot \cos \gamma = c \cdot \cos \beta$,

the following Odaka's equation are obtained:

(See Figure 2)

$$\left.\begin{aligned} \frac{1 - \dfrac{\cos \beta \cos \gamma}{\cos \alpha}}{1 - \dfrac{\cos \gamma \cos \alpha}{\cos \beta}} &= \left(\frac{e}{d}\right)^2 \\ \frac{1 - \dfrac{\cos \alpha \cos \beta}{\cos \gamma}}{1 - \dfrac{\cos \gamma \cos \alpha}{\cos \beta}} &= \left(\frac{e}{f}\right)^2 \\ \alpha + \beta + \gamma &= 4 R\angle \end{aligned}\right\} \quad \ldots\ldots\ldots\ldots (2)$$

where $\angle$ EOF $= \alpha$, $\angle$ FOD $= \beta$, $\angle$ DOE $= \gamma$, e = OE , d = OD, f = OF.

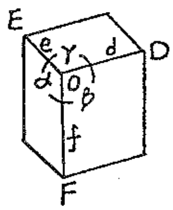


Figure 2

APPLICATIONS

From equations (2), a new formula for dimetric drawing is derived; and a commonly known formula for dimetric drawing is proved. The foreshortened scales for dimetric and trimetric projection can easily be obtained by using these equations and formulas.

1. In isometric drawing, the object is placed so that all three axes are at the same angle with the picture plane. Since $\alpha = \beta = \gamma$, therefore, from equations (2), we obtain e = d = f. Hence, in drawing, the projections of the three isometric axes use the same scale and make equal angles (120°) with each other.

2. In dimetric drawing, the object is placed so that two of its axes make the same angle (over 90°) and the third axis makes a different angle with the picture plane. The two axes, which make the same angle with the picture plane, are foreshortened equally. They use the same scale in drawing; and the third axis uses a different scale. An indefinite number of combinations of angles are available for dimetric drawing. Let's assume that the two equal angles are α and β , and thus $\cos \alpha = \cos \beta$. From equations (2), we obtain

$$\frac{1 - \dfrac{\cos \alpha \cos \beta}{\cos \gamma}}{1 - \dfrac{\cos \gamma \cos \alpha}{\cos \beta}} = \left(\frac{e}{f}\right)^2$$

substitute $\cos \beta$ with $\cos \alpha$ to the left side,

$$\frac{1 - \dfrac{\cos^2 \alpha}{\cos \gamma}}{1 - \dfrac{\cos \gamma \cos \alpha}{\cos \alpha}} = \frac{\dfrac{\cos \gamma - \cos^2 \alpha}{\cos \gamma}}{1 - \cos \gamma}$$

$$= \frac{\cos \gamma - \cos^2 \alpha}{\cos \gamma (1 - \cos \gamma)} ,$$

$$\text{since } \cos^2 \alpha = \left[\cos \frac{360^{\circ} - \gamma}{2}\right]^2$$

$$= \left[\cos \left(180^{\circ} - \frac{\gamma}{2}\right)\right]^2$$

$$= \left[- \cos \frac{\gamma}{2}\right]^2$$

$$= \frac{1 + \cos \gamma}{2} .$$

Therefore,

$$\frac{\cos \gamma - \cos^2 \alpha}{\cos \gamma (1 - \cos \gamma)} = \frac{\cos \gamma - \dfrac{1 + \cos \gamma}{2}}{\cos \gamma (1 - \cos \gamma)}$$

$$= \frac{2 \cos \gamma - 1 - \cos \gamma}{2 \cos \gamma (1 - \cos \gamma)}$$

$$= \frac{\cos \gamma - 1}{2 \cos \gamma (1 - \cos \gamma)}$$

$$= \frac{-1}{2 \cos \gamma} = \frac{e^2}{f^2} .$$

We now have $2 e^2 \cos \gamma = - f^2$,

$$\cos \gamma = - \frac{f^2}{2e^2} . \quad \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Equation (3) is the fundamental equation for dimetric drawing from which the angles and scales data for dimetric drawing can easily be obtained. As an example, considering that $\alpha = \beta = 103.5$, and $\gamma = 153^{\circ}$, we obtain by substituting into equation (3),

$$\cos 153^{\circ} = - \frac{f^2}{2e^2}, \text{ or } - 0.8910 = - \frac{f^2}{2e^2},$$

assuming that f = 1,

$$-0.8910 = -\frac{1}{2e^2},$$

$$e^2 = 0.5612,$$

$$e = 0.7491 \cong \frac{3}{4},$$

$$e = d = \frac{3}{4}.$$

The dimetric drawing of a cube for this example is shown in Figure 3.

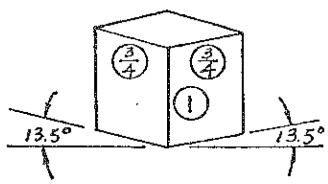


Figure 3

In a similar manner, an equation for dimetric drawing in regard to cos α or cos β can be obtained as follows:

Let $\alpha = \beta$, $\cos\alpha = \cos\beta$,

$$\cos\gamma = \cos(360^\circ - \alpha - \beta)$$

$$= \cos(360^\circ - 2\alpha)$$

$$= \cos 2\alpha$$

$$= \cos^2\alpha - \sin^2\alpha .$$

From equations (2),

$$\frac{1 - \frac{\cos\alpha\cos\beta}{\cos\gamma}}{1 - \frac{\cos\gamma\cos\alpha}{\cos\beta}} = \frac{1 - \frac{\cos^2\alpha}{\cos^2\alpha - \sin^2\alpha}}{1 - \cos\gamma}$$

$$= \frac{\frac{-\sin^2\alpha}{\cos^2\alpha - \sin^2\alpha}}{1 - \cos^2\alpha + \sin^2\alpha}$$

$$= \frac{\frac{-\sin^2\alpha}{\cos^2\alpha - \sin^2\alpha}}{\sin^2\alpha + \sin^2\alpha}$$

$$= \frac{-\sin^2\alpha}{\cos^2\alpha - \sin^2\alpha} \cdot \frac{1}{2\sin^2\alpha}$$

$$= \frac{-1}{2(\cos^2\alpha - \sin^2\alpha)}$$

$$= \frac{-1}{2(\cos^2\alpha - 1 + \cos^2\alpha)}$$

$$= \frac{-1}{2(2\cos^2\alpha - 1)} = \left(\frac{e}{f}\right)^2.$$

We now have

$$2e^2(2\cos^2\alpha - 1) = -f^2,$$

$$\cos^2\alpha = \frac{-f^2 + 2e^2}{4e^2}$$

since $180^\circ > \alpha > 90^\circ$,

$$\cos\alpha = -\frac{\sqrt{2e^2 - f^2}}{2e} \qquad \ldots\ldots\ldots\ldots\ldots\ldots (4)$$

Equation (4) is the commonly known formula (Giesecke et al., 1974, p. 516; Luzadder, 1977, p. 219; Martin, 1968, p. 84) for dimetric drawing, and is thus proved by Odaka's equations. As an example, considering that $\alpha = \beta = 127^\circ$, and e = d, we obtain

$$\cos\alpha = -\frac{\sqrt{2e^2 - f^2}}{2e},$$

$$\cos 127^\circ = -0.6018 = -\frac{\sqrt{2e^2 - f^2}}{2e},$$

assuming that e = 1,

$$0.6018 = \frac{\sqrt{2 - f^2}}{2},$$

$$1.4487 = 2 - f^2,$$

$$f^2 = 0.5513,$$

$$f = 0.7425 \cong \frac{3}{4},$$

$$e = d = 1.$$

Figure 4 shows such a dimetric drawing.

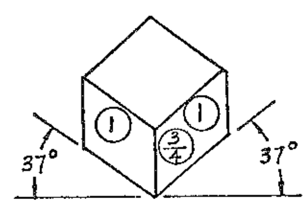


Figure 4

3. In trimetric drawing, all three planes are unequally foreshortened; therefore, the axes are unequally separated. Like dimetric drawing, an indefinite number of combinations of angles are available for trimetric drawing. Odaka's equations (2) for axonometric projection can be used to determine the foreshortened scales in

trimetric drawing. As an example, given $\alpha = 105^\circ$, $\beta = 115^\circ$, $\gamma = 140^\circ$, for a trimetric drawing, from Odaka's equations (2), we obtain

$$\frac{1 - \dfrac{\cos\alpha\cos\beta}{\cos\gamma}}{1 - \dfrac{\cos\gamma\cos\alpha}{\cos\beta}} = \left(\frac{e}{f}\right)^2,$$

$$\frac{1 - \dfrac{\cos 105^\circ \cos 115^\circ}{\cos 140^\circ}}{1 - \dfrac{\cos 140^\circ \cos 105^\circ}{\cos 115^\circ}} = \left(\frac{e}{f}\right)^2,$$

$$\frac{1.1428}{1.4629} = \left(\frac{e}{f}\right)^2,$$

let f = 1, $e^2 = 0.7779$,

$e = 0.88$

similarly,

$$\frac{1 - \dfrac{\cos\beta\cos\gamma}{\cos\alpha}}{1 - \dfrac{\cos\gamma\cos\alpha}{\cos\beta}} = \left(\frac{e}{d}\right)^2,$$

$$\frac{1 - \dfrac{\cos 115^\circ \cos 140^\circ}{\cos 105^\circ}}{1 - \dfrac{\cos 140^\circ \cos 105^\circ}{\cos 115^\circ}} = \left(\frac{e}{d}\right)^2,$$

substitute e = 0.88, we have

$d^2 = 0.5029$

$d = 0.71$

See Figure 5 for such a trimetric drawing.

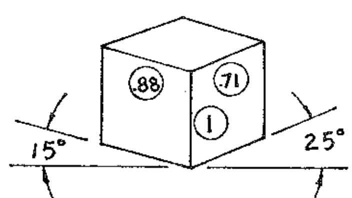


Figure 5

A dimetric or trimetric scale is not complete unless the angle-size ellipse guides are found for each plane. The proper ellipse templates can then be used to draw circular features by simply locating the center of the circle to be drawn. Customary methods of finding angle-size ellipse guides in dimetric or trimetric drawing such as the semicircles method (Sauvageau, 1971, p. 14; Thomas, 1978, p. 183) and the auxiliary views method (Brown, 1974, p. 207; Earl, 1977, p. 516) require not only a tedious process of constructing additional views but also a large space consumption. Through a mathematical analysis, Odaka (1978) has developed a third method which is more efficient and economical in every respect. The trimetric drawing of a cube found in Figure 2 is given. The angles of ellipse to be used on the front, right, and top planes are θ, ϕ, and η respectively. Odaka's equations for θ, ϕ, and η are in the following forms:

$$\left.\begin{aligned} \cos^2\theta &= \frac{\cos\alpha}{\cos\alpha - \cos\beta\cos\gamma} \\ \cos^2\phi &= \frac{\cos\beta}{\cos\beta - \cos\gamma\cos\alpha} \\ \cos^2\eta &= \frac{\cos\gamma}{\cos\gamma - \cos\alpha\cos\beta} \end{aligned}\right\} \quad \ldots\ldots (5)$$

The angle-size ellipse guides for axonometric drawing can easily be determined by using these equations.

1. In isometric drawing, we have $\alpha = \beta = \gamma = 120^\circ$, and $\cos\alpha = \cos\beta = \cos\gamma = -0.5$.

From equations (5), we obtain

$$\cos^2\theta = \frac{-0.5}{-0.5 - (-0.5)(-0.5)} = 0.6667$$

$\cos\theta = 0.8165$

$\theta = 35^\circ\ 16'$

$\theta = \phi = \eta = 35^\circ\ 16'$. (Use 35° ellipse)

2. In dimetric drawing, there are two equal angles. Let's assume that $\alpha = \gamma = 130^\circ$, and $\beta = 100^\circ$. From equations (5) we obtain

$$\cos^2\theta = \cos^2\eta = \frac{-0.6428}{-0.6428 - [(-0.6428)(-0.1736)]}$$

$= 0.8521.$

$\cos\theta = \cos\eta = 0.9231.$

$\theta = \eta = 22^\circ\ 37'$. (Use 25° ellipse)

similarly

$\cos\phi = 0.5439.$

$\phi = 57^\circ 03'$. (Use 55° ellipse)

(See Figure 6)

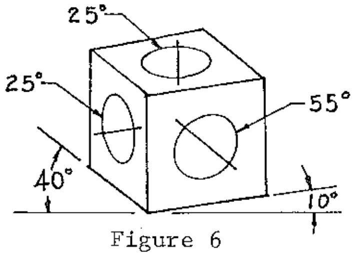


Figure 6

3. In trimetric drawing, there are three unequal angles. Let's assume that $\alpha = 115^o$, $\beta = 105^o$, and $\gamma = 140^o$. From equations (5), we obtain

$$\cos^2\theta = 0.6807.$$
$$\cos\theta = 0.8250.$$
$$\theta = 34^o24'.$$ (Use 35° ellipse for the front)

$$\cos^2\phi = 0.4445.$$
$$\cos\phi = 0.6667.$$
$$\phi = 48^o11'.$$ (Use 50° ellipse for the right)

$$\cos^2\eta = 0.8750.$$
$$\cos\eta = 0.9354.$$
$$\eta = 20^o43'.$$ (Use 20° ellipse for the top)

(See Figure 7)

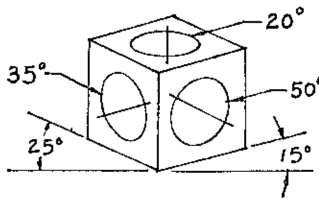


Figure 7

Since angle-size templates are commonly available in increments of 5°; this makes it necessary to select the size nearest the angles. For isometric, dimetric, and trimetric projections, the same 1" angle-size ellipse templates are used for all 1" circles. However, for isometric, dimetric, and trimetric drawings, one should use the 1 1/4" angle-size ellipse template for a 1" circle, because such drawings are made 1 1/4 times larger than the actual projection.

In sum, Odaka's equations of perspective projection are the mathematical foundations for all types of pictorial projection, Odaka's equations of axonometric projection, and equations (3) and (4) described in this paper, can be applied to the determination of scales in dimetric and trimetric drawings. Odaka's equations for the angles of inclination can be used more efficiently than conventional methods to find the angle-size ellipse guides in axonometric drawing.

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Jobs

The Engineering Design Graphics Department of Texas A&M University is seeking applicants for an assistant or associate professorship. Duties will include the teaching of engineering graphics and descriptive geometry to freshman engineering students. Applicants should be competent in and able to teach specialty courses such as computer graphics, electronic drafting, pipe and vessel drafting, nomography, etc.

It is preferred that applicants have a doctor's degree with at least one degree in a field of engineering. Salary is open based upon the qualifications of the applicant. Texas A&M is an equal opportunity, affirmative action employer.

Graduate Assistantships and part-time teaching positions are also available in the Engineering Design Graphics Department.

Contact James H. Earle, Engineering Design Graphics Department, Texas A&M University, College Station, Texas. Phone (713) 845-1633.

PUZZLE CORNER

SPRING '79 PUZZLE

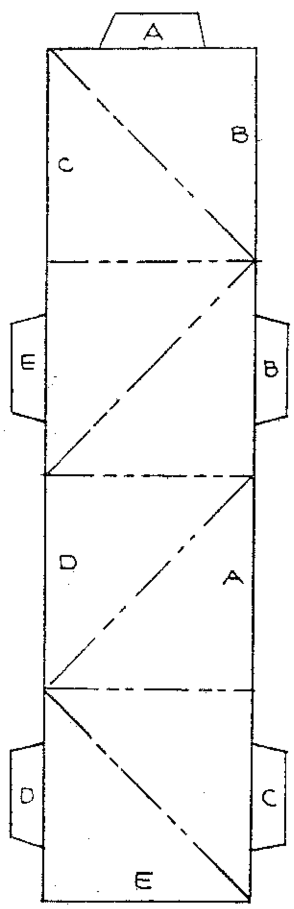
Given: Two successive orthographic projections of two oblique limited planes of arbitrary orientation that do not appear to intersect.

Construction: Without determining the line of intersection between the given planes, construct a third oblique plane such that it makes a specified angle with one of the given planes and a different specified angle with the other given plane.

Solutions will be published in the Fall issue. Please submit your solutions to:

Robert P. Kelso
Assistant Editor
Engineering Design Graphics Journal
Department of Industrial Engineering and Computer Science
Louisiana Tech University
Ruston, Louisiana 71270

Due to the short response time between the Winter and Spring issues this year, the solution to the "Perplexahedron" (repeated below) of the Winter '78-'79 issue will be deferred until the Fall issue. At this writing no solutions have been received (we did it, but DeJong must still be working) so help is needed!



WINTER '79 Puzzle

PERPLEXAHEDRON

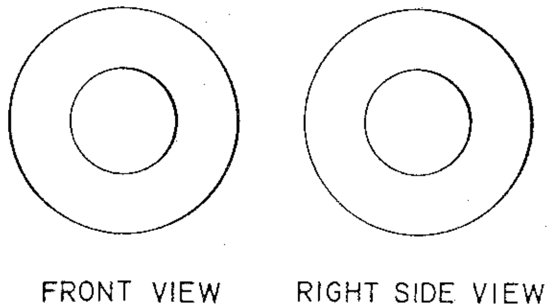
1. CONSTRUCT A PATTERN USING FOUR SQUARES AND DIAGONALS AS SHOWN.
2. ADD THE ASSEMBLY TABS AND LABELS.
3. CUT OUT THE PATTERN
4. FOLD ALL SURFACE LINES, KEEPING THE LINES AND LABELS ON THE OUTER SURFACE.
5. ATTACH THE TABS TO THE SURFACES, AT THE PLACES INDICATED, TO CREATE A CLOSED BOX.
6. YOU HAVE A STRANGE BOX WITH EIGHT IDENTICAL SURFACES AND SOME ANGLES THAT LOOK INTERESTING.

PROBLEM

USING CONVENTIONAL DRAWING METHODS AND TECHNIQUES (NO CALCULATIONS) CONSTRUCT TWO PRINCIPAL VIEWS OF THIS PERPLEXAHEDRON

WINTER '78-'79 "Filler" Problem

Complete the top view



Figures 1, 2, and 3 are solutions to the Winter '78-'79 "Filler" problem. Figure 1 was suggested by Paul Strickland, a student at Louisiana Tech University. There are probably infinite possible variations and combinations on these themes (especially, on Figure 3). For instance, the "circular" appearing center piece might be negative (and seen as a hidden line in the top view).

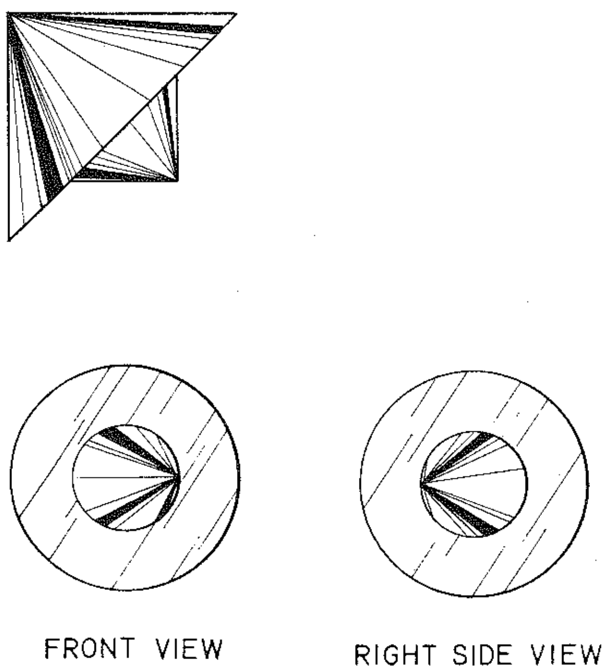


Figure 1

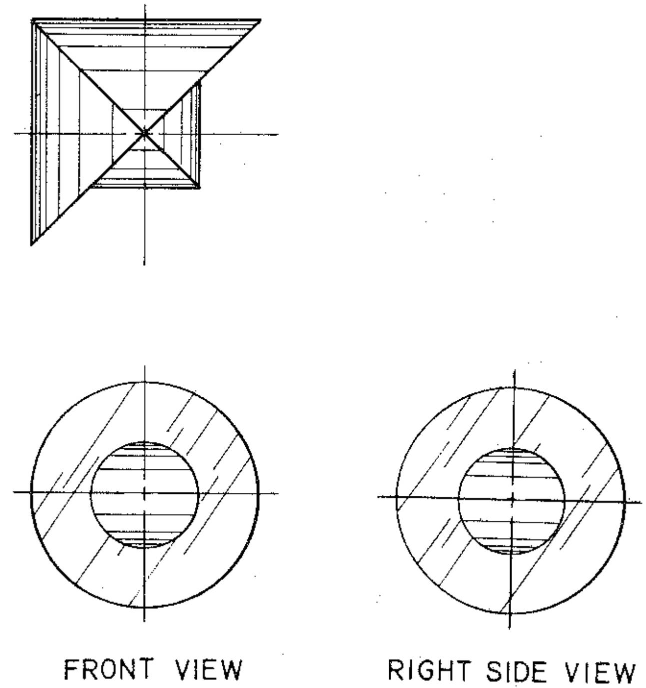


Figure 2

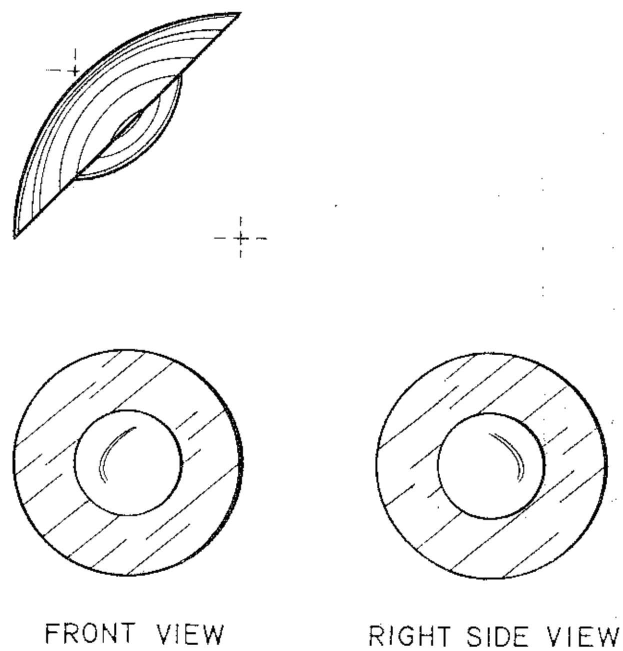


Figure 3

Note that normal views of the plane's surface will project as ellipses.

We are interested in receiving more unique solutions.

The 'Corner' also needs puzzle candidates for future issues so if you have a good one up your sleeve send it in. Anything is fair game-visualization problems or what-have-you.

Abe Rotenberg of the University of Melbourne has contributed a proof to go with his solution of the Fall '78 Puzzle. His solution ran in the Winter issue.

The problem again:

Given: Two limited skew lines of arbitrary orientation and length in adjacent orthographic views.

Find: The general condition* (or "most general solution") which will yield all-views-of-the-two-lines-in-which-they-appear-equal-in-length.

*a geometric configuration so oriented in space such that the elements of the figure represents lines of sight, all of which will yield views of the given lines as appearing equal.

Solution: Figure 4.

Proof: See Figure 5.

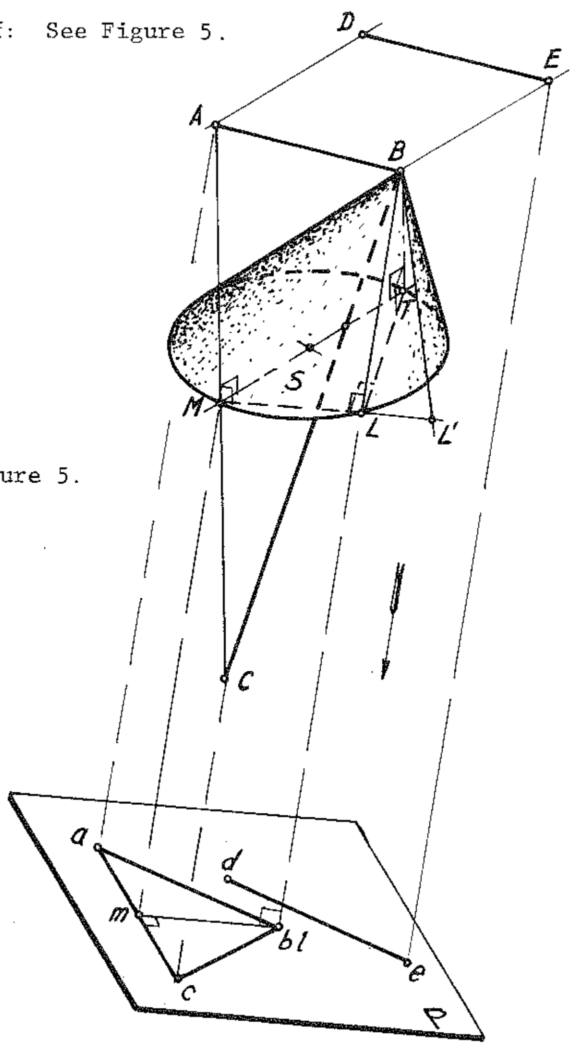


Figure 5.

Let BC and DE (Figure 5), BC≠DE, be two arbitrary lines.

(i) Draw AB such that AB=DE and AB//DE;
(ii) Construct a cone with its vertex at B and having a circular base satisfying the following conditions:

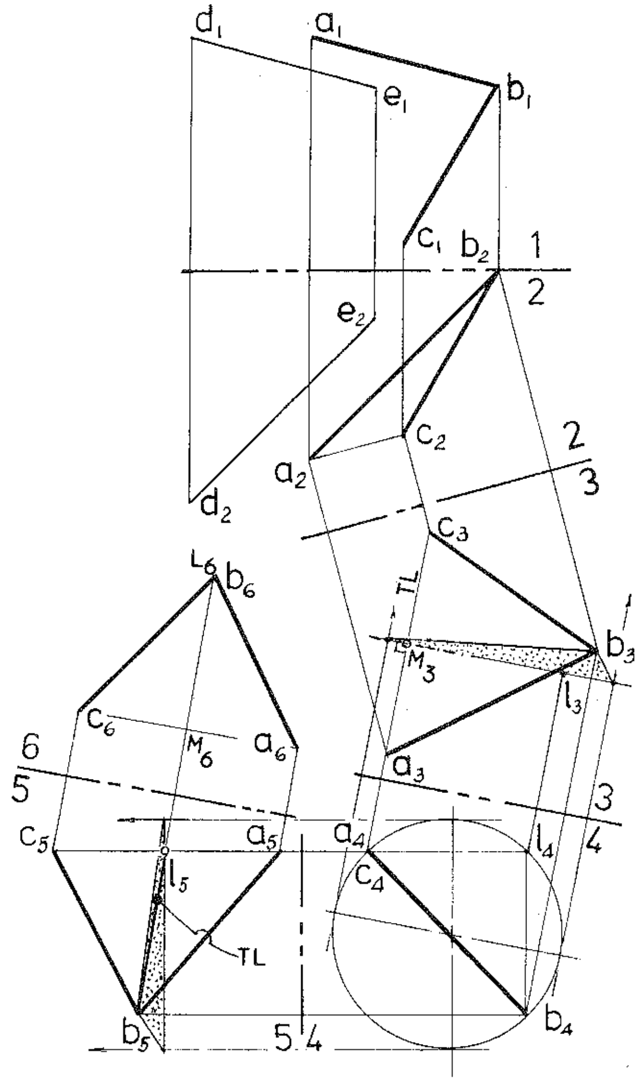


Figure 4

(a) the base plane S⊥AC;
(b) the base plane S passes through the midpoint M of AC (AM=MC);
(c) the diameter MT of the base circle is an orthographic projection of AB on the plane S.

Then,
I. ANY orthographic view in the direction of ANY straight line generator of the above cone is a solution of the problem.

and conversely,

II. An orthographic view in a direction NOT parallel to any of the straight line generators of the above cone is NOT a solution of the problem.

NOTE: For BC=DE,
The cone degenerates into the plane S. All generators of this "cone", except BT (BT⊥S), become lines in the plane S, and BT becomes a point of S. Orthographic views in the direction of any line in the plane S and in the direction AC are solutions of the problem in this case.

PROOFS of propositions I and II:

I. Let BL be an arbitrary generator of the cone. Then $ML \perp TL$ (since MT is a diameter of a circle passing through the point L) and, hence, $ML \perp BL$ (the "three-perpendiculars theorem": if a line ML in a plane S is perpendicular to a projection TL-of-a-line-BL-on-S, then $ML \perp BL$).

It follows that, in an orthographic view in the direction BL (i.e. in an orthographic projection on a plane $P \perp BL$),

(i) $lm \perp ac$ (since $P \parallel LM$ and $AC \perp LM$);
(ii) am=mc (since AM=MC);
(iii) b coincides with l (since $P \perp BL$).**

Hence ab=bc and, since two parallel lines (AB and DE) equal in length will remain parallel and equal in <u>any</u> orthographic view, de=bc, q.e.d.

** Lower case letters are used in this proof to denote orthographic projections of the corresponding points in space.

II. Let L' be an arbitrary point in the plane S not on the circumference of the base circle of the cone. We will demonstrate that the orthographic view in the direction BL' is NOT a solution of the problem.

In the view in the direction BL', b will coincide with l' and am=mc (since BL' is the direction of viewing and AM=MC). Hence for ab to be equal to bc, in this view, it is necessary that $ac \perp ml'$. But two mutually perpendicular lines, AC and ML', will appear in an orthographic view as mutually perpendicular if and only if at least one of them is parallel to the projection plane. Clearly, since BL' is not perpendicular to ML' or to BT ($BT \parallel AC$), there exists no projection plane which is parallel-to-ML'-or-AC-and-which-at-the-same-time-is-perpendicular-to-BL'. It follows that an orthographic view in the direction BL' is NOT a solution of the problem, q.e.d.

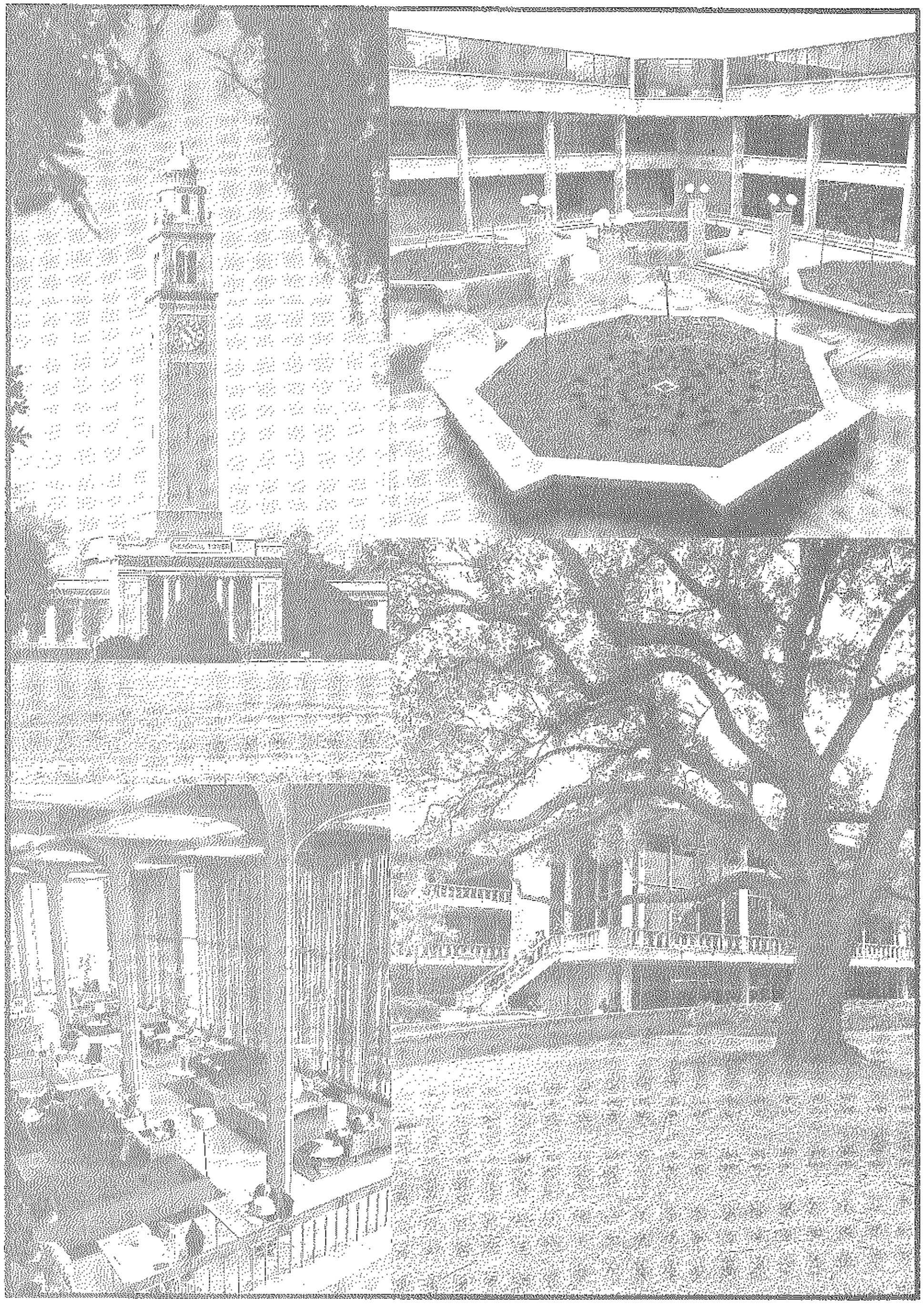
See you in Baton Rouge!

Robert P. Kelso

<u>GRAPHICS IN MECHANICS</u>, concluded from p.18

problems. The larger obligation is to develop an understanding of concepts and the capacity to use this understanding creatively by bringing students into contact with new and nonroutine problems. This objective is often lost when instruction centers on the solution of oversimplified problems designed mainly to illustrate a principle and to test manipulative facility. It is only when principles are called upon to help solve problems which are new, interesting, and possess significance of application that these broader objectives can be realized.

The intelligent use of graphics in mechanics is a prime instrument in approaching these objectives. Therefore, a revitalization of the use of graphics in mechanics is necessary to get on with the job of producing creative and productive engineers who can use effectively their "mind's eye".



CIRCULATION MANAGER

GARLAND K. HILLIARD, JR.
239 RIDDICK HALL
NORTH CAROLINA STATE UNIV.
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