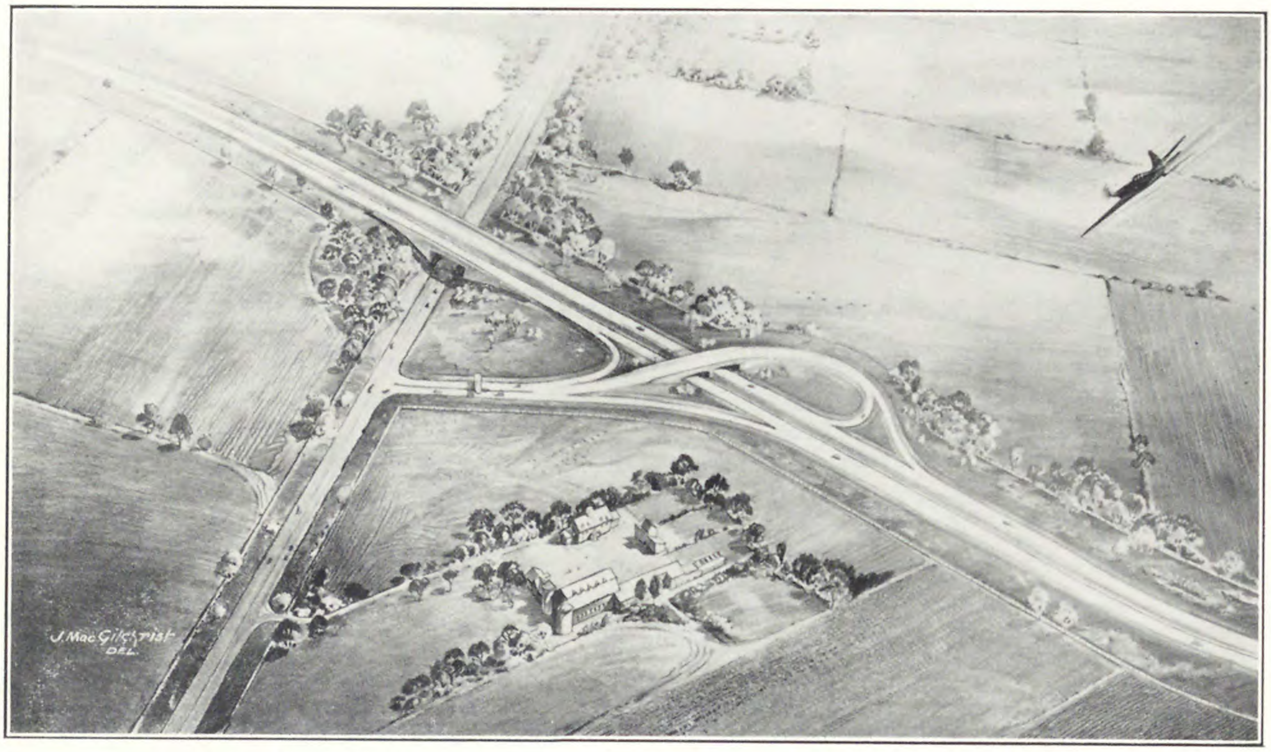
Newark Engineering Notes, Volume 3, No. 3, March, 1940

Newark College of Engineering

NEWARK ENGINEERING NOTES



Example of the type of Interchange to be used on the Pennsylvania Turnpike

VOLUME 3
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Photograph Courtesy of Mr. Thomas H. MacDonald, Commissioner of Public Roads, Federal Works Agency, Public Roads Administration, Washington, D. C.

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From time to time you will receive a copy of the NEWARK ENGINEERING NOTES. In case you wish to receive this magazine regularly, the only thing you have to do is to write us and say so. Address your letter to the Editor, Newark Engineering Notes, Newark College of Engineering, Newark, N. J.

THE PRESIDENT'S DIARY

February 15

I have been considering for a long time the general development of the Technical School. There have been many discussions among faculty members and with representatives of other institutions in this metropolitan area, and we have just about decided to institute, in connection with the work of the Newark Technical School, certain courses of a technological rather than of a technical nature. I am not sure that the dictionary would express the difference that I want to bring out as between these two words.

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I remember, when I first came to Newark, over twenty-one years ago, that the Technical School had courses in plumbing, tool making, auto mechanics, and other courses along those general lines. There has lately come a great call and a great public need, I think, in the industrial field for courses in some subjects such as refrigeration, air conditioning, electronics, diesel engines, etc., and these last courses I look at as technological rather than technical, in the old sense of the word. Of course, what it means is that, as engineering and technology advance, there become more and more opportunities to help young men advance themselves and it is also true that these opportunities progressively require in each decade a little more in the way of a mathematical and a scientific foundation.

So far as the courses being usable for credit towards an advanced degree is concerned, it is not our intention to make that the primary criterion. It is perfectly true that many advanced courses of this type cannot command credit for either a Master's degree or a Doctor's degree, but it is nevertheless true that they can be of the greatest benefit so far as the young men of the locality are concerned. It is our plan and our hope therefore to develop, as we go on, increasingly more courses of a technological or, let us say, of an advanced character, advanced simply because they meet the present needs of an advancing technology.

There is another point that is becoming quite evident in a study of the situation in this urban community, and that is that there is a great need for courses which deal with administration, management, accounting, time study, economics, and many subjects which are considered a part of a traditional course in industrial engineering. It seems to me that when young men graduate from college, they are very much interested at that time in further intensive specialization, and many of them take up advanced work along the line that they have followed in college. After three or four or five years out, if they are advancing, as a great many of them are, they begin to appreciate that a great opportunity lies in the field of administration in all its phases, in the field of sales, of marketing, of financial control, and they begin to appreciate that problems of accounting and problems of management are perhaps just as fundamental, if not more fundamental, in any engineering organization as are questions of pure technology. About that time these students come back and want something in the way of management or accounting. They still are very much interested in the technical side but are beginning to appreciate the necessity of some foundation in what we might call the basic business or organizational procedure, and, after about ten years, in very many cases this type of management and accounting work represents their greatest need.

February 29

Now, while this institution has the right to give courses in business or accounting, there seems to be no point in duplicating work which is satisfactorily given by many institutions in this locality, and so, courses in general economics or in bookkeeping or accounting as such would not be indicated. However, there is certainly a great need and an ever increasing need for courses in executive control and management and cost accounting as applied to technical and industrial organizations, and it is our hope that we may institute this next year and expand our courses in the evening along these lines.

One other thought in this connection seems important, and that is that gradually it is being made evident to us, who are interested in engineering, that the human problems, the personal problems, the organizational and management problems having to do with human beings, are of the utmost importance. Both internally and externally to for instance the public utilities, the reaction of people to the organization is of the utmost importance. Coöperation, efficiency, effectiveness, loyalty, are all fundamental to profit in any organization, and no one could say that the question of labor relations and its relation to the general question of trade unions is a thing of no considerable importance.

Customer relations, advertising in any of its forms, sales, marketing, and kindred subjects, are susceptible to analysis, and many times to fundamental scientific analysis, and the young engineer is needing and demanding definitely some instruction, or, better let us say, stimulation to thought, along these particular lines. This amounts to saying that in this democracy of ours, even from a technological standpoint, we are going to pay a little more attention to the human units in the future, say in the next twenty years, as we did to the machine units and the financial units in the last twenty years, because both of the latter are dependent upon the former to a very considerable extent, and perhaps a relation between the three—men, money, and materials—is the thing which brings the largest return to the young engineer. We hope to have an increasing number of courses touching this particular phase of engineering. These things are not with us idle guesses, but over a period of years we have been, as we hope we always shall be, able to do a little experimenting to find out just what the community needs most in the way of technical training.

Perhaps sometimes what the community wants most is not what it needs most, but, in a public institution, supported by the taxpayers and where the taxpayers are both the donors and the beneficiaries, it is incumbent upon us to study closely the needs of the particular locality which we serve, and it would be well for those who are interested in the development of the school along sound lines, meeting the needs of Newark and its adjacent territory, to understand what some of these courses stand for and the philosophy which underlies their establishment and expansion.

Why not take the opportunity to write me your reaction?

ALLAN R. CULLIMORE

February 29, 1940

THE VECTOR IDEA IN TRIGONOMETRY

By EDWARD BAKER, A.B., A.M., Ed.D.

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Introduction

Trigonometry as organized from the point of view of an engineer is quite different from trigonometry as expounded in current textbooks. The engineer's attitude towards trigonometry is highly characteristic. He thinks of it in terms of its usefulness for solving his professional problems.

Engineering problems that involve trigonometry are in most cases vector problems. In surveying, for example, latitude and departure are merely special technical names for the components of certain space vectors; and although for historical reasons it is not customary to emphasize the vector aspect of triangulation, the vector concept is a powerful agent for simplifying and unifying the theory of surveying. Argument is presumably unnecessary to show the dependence upon the vector idea of theories of electricity, machine design, structural analysis, and other basic technological studies.

In recent years there has been a tendency for textbooks to make minor concessions to the needs of the engineering student by including, as a special topic, a cursory treatment of vector applications. Nevertheless, a wide gap exists between trigonometry of the classroom and trigonometry as encountered in professional engineering studies. The Mathematics Division of the Society for the Promotion of Engineering Education has recognized the existence of this gap by appointing a committee to study ways of bridging it.[1]

It is the purpose of this paper to present in abridged form a practical method of teaching trigonometry, in which the engineering point of view is adopted from the start. Though the method is not lacking in mathematical elegance and simplicity, its most important claim to attention from the teacher of engineering mathematics is that it is designed to meet the needs of the engineering student as directly as possible.

Undefined Terms

Engineers have daily experience of quantities like force and velocity—quantities characterized by direction as well as magnitude. They are usually represented in diagrams by a line segment with an arrowhead, called a line vector.

Let **H** be a vector specifying a fixed direction in space. In most engineering and scientific work, and indeed in everyday life, the fixed direction will be given by a field of some kind. For instance, a vertical direction is specified by the earth's gravitational field. The north-south direction is fixed by the earth's magnetic field or by the angular velocity vector of the earth.

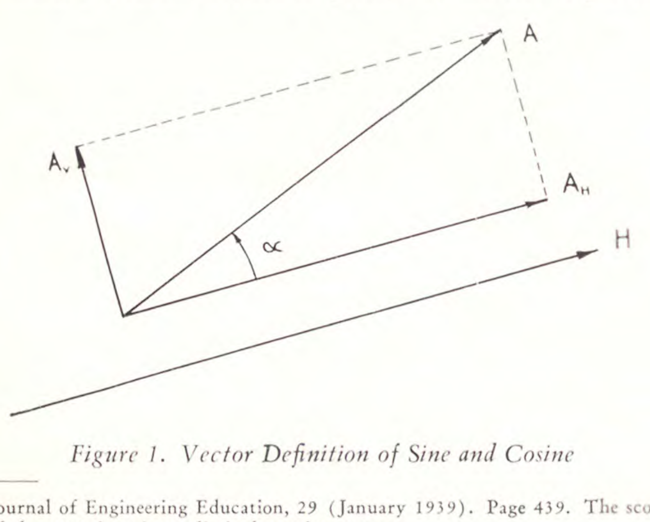

Figure 1. Vector Definition of Sine and Cosine

Let **A** be a vector making an angle α with **H** (see Figure 1).

Definitions

The cosine of α is the numerical factor by which **A** must be multiplied to give its projection or component in a direction parallel to **H**.

The sine of α is the numerical factor by which **A** must be multiplied to give its projection or component in a direction perpendicular to **H**.

The tangent of α is defined as $\frac{\sin \alpha}{\cos \alpha}$. The remaining functions are defined as reciprocals of these three.

Rotating Vectors

If these definitions be applied to Figure 2, the sine and cosine may be visualized as the horizontal and vertical components of a rotating unit vector. This vector may be concretely represented as a one-foot spoke in a revolving wheel. The shadow of the spoke cast by the sun when directly overhead represents the cosine function.

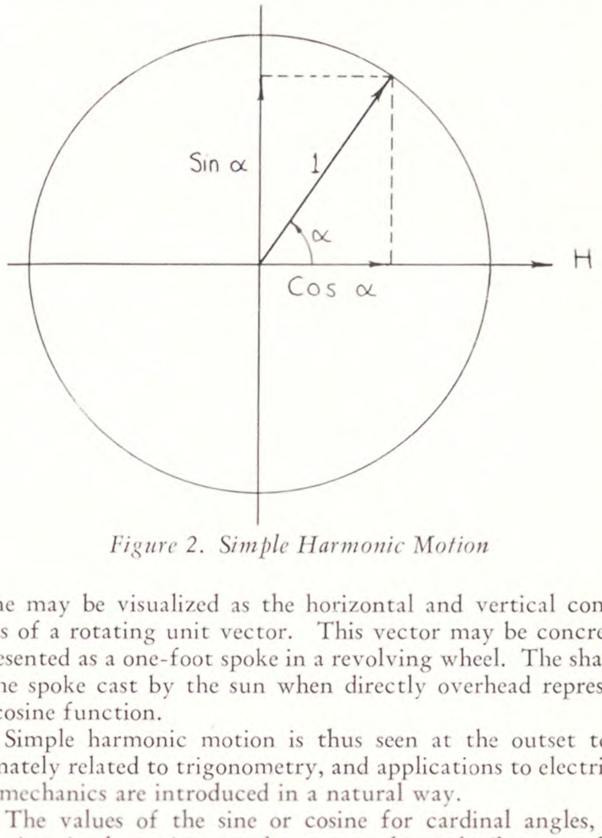

Figure 2. Simple Harmonic Motion

Simple harmonic motion is thus seen at the outset to be intimately related to trigonometry, and applications to electricity and mechanics are introduced in a natural way.

The values of the sine or cosine for cardinal angles, and their signs in the various quadrants, may be read off at once from Figure 2. It may also be seen that for a right triangle the definition of tan α reduces to the familiar expression $\frac{\text{opposite leg}}{\text{adjacent leg}}$.

Solving Triangles

The common practice at present is to give most time and attention to those cases which are of least importance to the engineer. It is doubtful whether the law of tangents should be included in the course, since instances in which its use is advantageous are rare; problems of the side-angle-side type in practice usually are solved by simpler means, as is indicated below. As for the half-angle formulas, there is no engineering problem known to me that is made easier by their use.

[1] Journal of Engineering Education, 29 (January 1939). Page 439. The scope of the committee is not limited to trigonometry.

On the other hand, far more attention should be given to right triangles than is customary. A wealth of technical material is available upon which to draw for right-triangle problems that are both interesting and important.

It will be noted that real-life problems are nearly all included under two cases, corresponding to the resolution and composition of vectors.

Case I. Given the hypotenuse and an acute angle. The legs may be found by direct application of the definitions of sine and cosine.

Case II. Given two legs. An acute angle may be found by means of the tangent function, and the hypotenuse may then be calculated by means of the sine.

In principle, all oblique triangles may be dealt with by breaking them up into right triangles.

For example, let an angle A and the two adjacent sides of a triangle be given (Figure 3). If an altitude be drawn as shown,

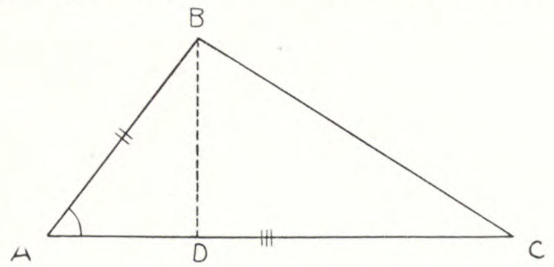

Figure 3. Oblique Vectors Lead to Laws of Sines and Cosines

it is seen that ABD may be solved as a *Case I* right triangle; and thereafter BCD may be solved as a *Case II* right triangle. A literal treatment of this problem leads directly to the Law of Sines and the Law of Cosines, which suffice to solve all oblique triangles.

Coffer Dam Problem

If one accustoms himself to the vector point of view, he finds that his way of approach to most problems in trigonometry is changed. For example, suppose that in the construction of a certain bridge, it is necessary to locate a driven pile, forming part of a coffer dam, at a point D upstream from the bridge. A base

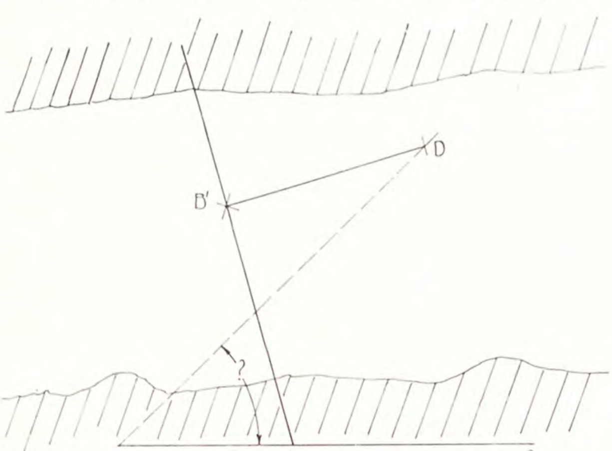

Fig. 4. Sketch for the Coffer Dam Problem

line (Figure 4) AC = 500.0 feet long is laid out on shore. The center-line of the bridge, BB', makes a measured angle of 74°37' with the base line. AB = 207.1 feet, BB' = 305.4 feet, and B'D is to be 250.0 feet in length in a direction perpendicular to the bridge line. The driving of the pile at D will be controlled by sighting transits along AD and CD. At what angle with the base line must the instrument be set, sighting from A?

There are of course several obvious ways of attacking this problem. The simplest and best is to consider AD to be an unknown vector, the resultant of three known vectors AB, BB', and B'D. The component of AD along the base line is

$$207.1 - 305.4 \cos 74°37' + 250.0 \sin 74°37'$$
$$= 367.1 \text{ feet}$$

In like manner, the perpendicular component of AD is found to be

$$305.4 \sin 74°37' + 250.0 \cos 74°37'$$
$$= 360.8 \text{ feet}$$

These results come directly from the definition of sine and cosine.

It is now necessary to solve a right triangle of the second kind. The tangent of the unknown angle is

$$\tan A = \frac{360.8}{367.1}$$
$$A = 44°30'$$

Glancing back at the definitions of the trigonometric functions, one may see in the light of this example that they have been defined in a way that corresponds to their most important use. It is quicker and more direct to think of the cosine as a multiplying factor of projection than as the ratio of two sides of a right triangle. One may observe that it is quite unnecessary to consider any triangle in finding the projections of BB' or B'D.

The vector idea tends to strip such problems as the above of irrelevant technical details. It provides a systematic method of attack which is the same for problems in surveying as for problems in electricity. One may readily construct problems from other technical fields that are formally identical with the coffer dam problem.

Analytic Trigonometry

By rotating **H** (Figure 1) through ninety degrees so that the vector **A** makes an angle (90° — α) with the fixed direction, it can be seen from the definitions that the sine of an angle equals the cosine of the complementary angle.

Now the vector **A** and its components $\mathbf{A}_h$ and $\mathbf{A}_v$ are equivalent systems, in that their projections in any direction are equal. If **A** were a force, it could be replaced by its components without affecting the behavior of a body upon which it acted. This fact leads to the fundamental theorem of analytic trigonometry. Let **A** and its components be separately projected in a direction indicated by a vector **B** (Figure 5).

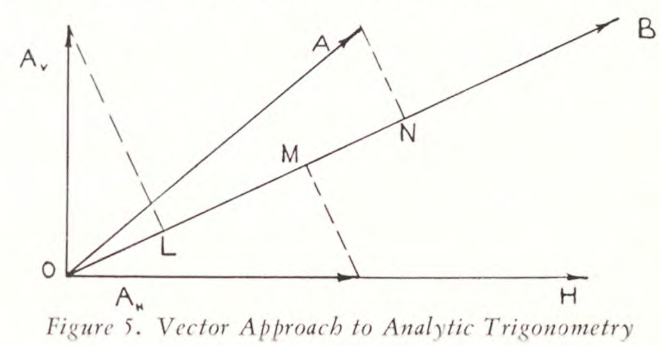

Figure 5. Vector Approach to Analytic Trigonometry

Then ON = OM + OL

I.e., (Proj. of **A**) = (Proj. of $\mathbf{A}_h$) + (Proj. of $\mathbf{A}_v$)

But (Proj. of **A**) = (Length of **A**) $\cos(\alpha - \beta)$

(Proj. of $\mathbf{A}_h$) = (Length of $\mathbf{A}_h$) $\cos\beta$

= (Length of **A**) $\cos\alpha \cos\beta$

(Proj. of $\mathbf{A}_v$) = (Length of $\mathbf{A}_v$) $\cos(90° - \beta)$

= (Length of **A**) $\sin\alpha \sin\beta$

If **A** is taken to be a unit vector, we have from the definitions

(1) $\cos(\alpha - \beta) = \cos\alpha \cos\beta + \sin\alpha \sin\beta$

From this fundamental equation, the whole of analytic trigonometry may be deduced. If β be taken equal to α, the result is

(2) $1 = \cos^2\alpha + \sin^2\alpha$

(Please turn to page 15)

INTERCHANGE DESIGN ON THE PENNSYLVANIA TURNPIKE

By HARVEY W. SARVEN, B.S.

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General Considerations

Across the Allegheny Mountains of Pennsylvania there is now under construction a superhighway known as the Pennsylvania Turnpike. This express highway, having two twelve-foot lanes of traffic in each direction separated by a ten-foot safety strip, will connect the City of Harrisburg with the City of Pittsburgh. It is the latest word in highway construction, designed for speed, safety, and riding comfort. Nowhere along its entire length is there a grade of more than three per cent, nor is there a single grade crossing, nor a curve with a radius sharper than six degrees (995 feet).

In a road of this length it is necessary to provide points of connection with existing roads, such points of connection being called Interchanges. Interchanges, then, are points where traffic can enter or leave the main highway. This article discusses the methods and certain standards as used in the designing of the several Interchanges along the Pennsylvania Turnpike.

The type of Interchange used on the Pennsylvania Turnpike consists of accelerating and decelerating lanes leading to ramps which converge to a single connection with the existing highway. This type of Interchange has one off-bound and one on-bound ramp for traffic in each direction. Inasmuch as the Turnpike is to be a toll road, toll booths are located at this point of convergence, and by this design only one toll booth for each Interchange is required.

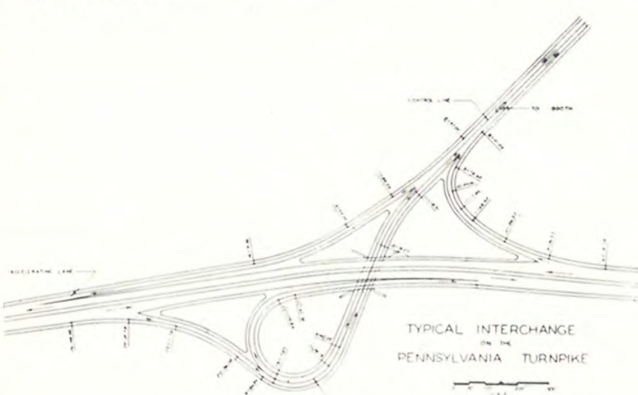

Fig. 1. General Scheme of Typical Interchange

The first step in Interchange design is the making of a traffic study. An Interchange must be located where it will receive the greatest volume of potential traffic, as the cost of construction would not be warranted where only a small volume of traffic through the Interchange existed. Traffic survey analyses were made of all possible points of connection, and potential traffic through the Interchange was estimated. Inasmuch as traffic is dependent upon population and industrial trends all available data on state planning were consulted. After all information was carefully studied it was possible to determine the necessity for an Interchange at any probable point along the route.

After the general location of an Interchange was determined, the next step was to study surrounding topography and other physical features in order that an exact location of the Interchange could be set. This consisted chiefly in the study of earthwork, as excessive cuts and fills were not desirable from both an economical and safety standpoint. This study determined whether the Interchange approach road was to pass over or under the Turnpike, as topography set the conditions. The preparation of a Preliminary Interchange Drawing was now in order.

Preliminary Interchange Drawing

The preliminary plan, drawn on a scale of 50 feet to the inch, showed all horizontal alignment and approximate ramp grades that were required. All ramp grades were held to less than five per cent if possible, and if grades ran higher it was necessary to make a new Interchange location study. Grades on down-grade ramps could be a little steeper than up-grade ramps without serious objection. The bridge clearance between approach road and Turnpike was made at least eighteen feet. Interchanges were placed on tangent sections of the Turnpike where possible, but in several cases they were placed on curves, without serious objection, because of the very flat curves used along the center line of the route. Preliminary drawings showed diagramatically the amounts of cut and fill at any point in the following manner:

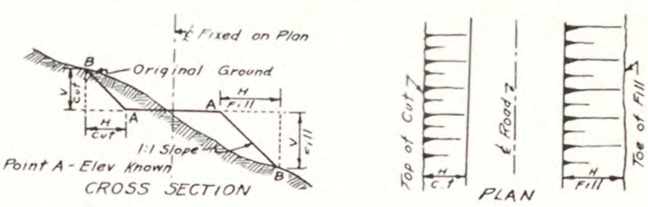

Fig. 2. Method of Showing Cuts and Fills on Preliminary Interchange Drawings

Determination of top of cut or toe of fill was determined in the same manner that slope stakes might be set. First horizontal distance H, where cut or fill intercepted the ground, had to be estimated, thus determining point B, and giving vertical distance V. Then knowing slope, say 1:1, it was possible to get exact distance H over to give difference in elevation V. If this figured distance was not approximately the same as the first estimated distance H, then another trial must be made. It is usually possible to set slope lines close enough on the first or second trial in this way. This method of showing earthwork worked out very satisfactorily.

No actual computations were made for any alignment on the Preliminary Drawings; all alignment was to be computed later on the theory that "what you can draw, you can figure." The next step was the preparation of the Control Drawings which showed all horizontal alignment as actually computed.

Control Interchange Drawing

The preparation of Control Drawings and computation of all curve and alignment data proceeded more or less simultaneously. Control Drawings were also plotted on a scale of 50 feet to the inch. One side of pavement on the Control Drawing was selected as the basis of computation, and was called the control line. All alignment was figured on this line, the other edge of pavement being concentric to this control line. The task of actually computing the Interchange so that it could be staked out in the field was done by using a system of rectangular coördinates. The intersection of the center lines of the Interchange approach road and Turnpike was assumed as having coördinates 10,000 N and 10,000 E, and all other points were figured from this origin. The general procedure of figuring the Interchange was to fix certain points and curve data, and then compute other points and closing curve data in order that the final design would closely approximate the design as first drawn on the Preliminary Plan. All curves were compounded several times to make for smooth transitions, particularly on the ramps leading directly from the decelerating lane. Pavement widths of twelve feet were widened to fifteen feet on curves to allow for the tracking of vehicles. The completion of these computations definitely fixed all curve data, tangent lengths and bearings, thus completely tying the design together. All computed data was then placed on the Control Drawing, including curve data (radius, degree, central angle, length, and tangent distance), tangent bearings and lengths, and stationing along the control line. Lengths of all curves were computed along the arc where the radius was sharper than five degrees, as it was in most cases. Stationing was assumed to start at station 1+00 at the intersection of the control line with the center line of the existing road to which the Turnpike was connecting. The coördinates of all points of curvature, and points of compound curvature, centers, and other important points were placed on the Control Drawing. All coördinates were given to the nearest hundredth of a foot, and all bearings to the nearest second. On this drawing all horizontal alignment was definitely fixed, and the information on the drawing was of great help in laying the Interchange out on the ground. Most points were staked out directly from the system of coördinates, giving much more accurate results than if the curves were run in from the given curve data.

Final Interchange Drawing

The Final Interchange Drawing was drawn very accurately on "hard copy" drawing paper to a scale of 30 feet to the inch. The first step was to coördinate the sheet of paper so as to accommodate the entire Interchange as computed and given on the Control Drawing. All coördinates appearing on the Control Drawing were plotted on this final drawing, including centers of curves when they fell within the limits of the paper. All curves, where possible, were drawn in with a beam compass, it sometimes being necessary to use a beam four or five feet long. If the center line of the Turnpike happened to be on a curve through the Interchange, it was necessary to plot this curve by tangent offsets or a similar method, as it was impracticable to swing an arc with so great a radius. Curve boards were used in connecting plotted points, but were not relied upon to lay in the entire curve. A simple method of plotting large radius curves of this nature is as follows:

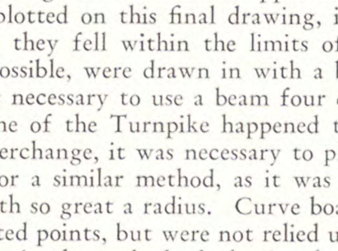

Fig. 3.

Given: A simple curve, its radius and central angle. The following relationships are true:

$$\begin{cases} \sin \alpha = \dfrac{x}{R} \\ \text{vers } \alpha = \dfrac{y}{R} \end{cases} \qquad \begin{cases} x = R \sin \alpha \\ y = R \text{ vers } \alpha \end{cases}$$

Then for any value of α, less than the central angle, the corresponding values of x and y can be computed, thus determining point P, in Fig. 3. Any number of points can be plotted in this manner, and a smooth curve drawn through them will be the required curve.

Through the entire plotting of this drawing a very careful check was constantly made to see if all arc lengths and other data scaled exactly as computed, thus giving a good check on all computations. From the finished drawing it was an easy matter to scale any distance to the nearest foot. A drawing of this nature proved very valuable in that any information could be scaled to the nearest foot directly from the drawing. The only information given on the drawing thus far was the stationing along the control line, and stationing along the Turnpike center line. For all other information, including curve data and coördinates, one had to refer to the Control Drawing.

Now, with the final plan completed, all that remained to complete the Interchange design was the determination of final paving profiles, and the contouring of the plan. Contouring, in this sense, means drawing on the plan all actual contours of the finished pavement, and landscaping. This served the purposes somewhat similar to that of a contour map, except that all contours were "man made," and drawn in very accurately. The determination of final paving profiles and contouring proceeded together, as one is dependent upon the other if smooth vertical intersections are to be obtained. All paving contours were drawn to a 0.2-foot interval, thus making it possible to scale from the Final Drawing the elevation of any point to the nearest 0.1 foot quite accurately. Shoulders and landscaping contours, however, were drawn to a one-foot contour interval. A plan contoured in this manner proved very useful in studying the drainage problems to be designed for at the Interchange.

In proceeding with the contouring the first step was the drawing of a profile of the center line of the Turnpike to the following scales: horizontal, one inch to thirty feet; vertical, one inch to two feet, the horizontal scale being the same as that used on the Final Interchange Drawing, and the vertical scale representing the 0.2-foot contour interval. Points of elevation to every 0.2 foot were plotted along the Turnpike center line on the final plan. In the case of the Turnpike the stationing of all points to 0.2 foot difference in elevation were actually computed, but in the case of the ramps the stations of the 0.2-foot points were scaled from the profile, and then transferred to the plan. The general procedure in working up a profile and contouring for the intersection of a ramp with the Turnpike might be as follows:

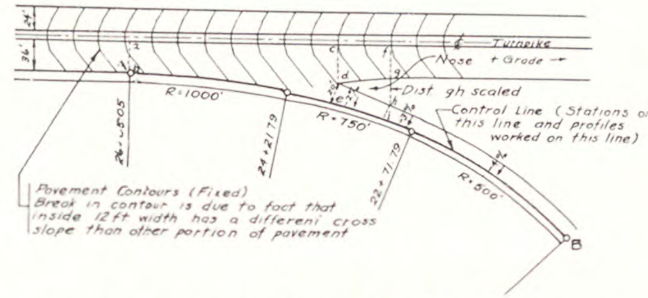

Fig. 4. Showing Procedure in Working Up Pavement Contouring at Nose of Deceleration Lane

Elevations along the Turnpike center line are fixed and have been plotted accordingly. Pavement contours along the Turnpike are next drawn to the specified cross slope, and Turnpike contouring was then fixed and complete. The profile along control line on ramp AB, for example, has been previously set by the Preliminary Plan, but must now be determined very accurately in order to have a smooth vertical intersection with the Turnpike. Inasmuch as the Turnpike grade was definitely fixed the ramp profile had to take all of the adjustment. Elevations at points a, c, and f are definitely known, as fixed by the Turnpike grade; also allowable cross slope across nose and ramp banking is known. It is then a simple matter to figure elevations at points b, e, and i on the control line by merely coming across known or scaled distances at specified cross slopes and banking. A series of points determined in this way and plotted on profile paper shows what the final ramp profile must look like in order that we have a smooth vertical transition. The problem, then, is to get a grade, or a series of grades, to pass through the fixed points as just plotted. It is usually necessary to have several small breaks in grade to produce the desired result. Small vertical curves between these breaks were introduced, but usually the grade break was so small that no vertical curve was required.

After the profiles along the control line were thus determined the next step was the plotting of the profiles for the opposite side of pavement. This was done by merely dropping or raising the elevation of the opposite side by the percentage of banking multiplied by the known roadway width. A profile of both the high and low side of pavement was then completed.

The next step was the transferring of the profile information to the plan, or contouring the pavement. As stated previously profiles were to a horizontal scale of 30 feet to the inch and a vertical scale of 1 inch to 2 feet. By using these scales it was possible to transfer grade information to the plan by merely laying a strip of adding machine paper along the profile, as shown in Fig. 5, and projecting down on the strip of paper the points of stationing of each 0.2 foot difference in elevation.

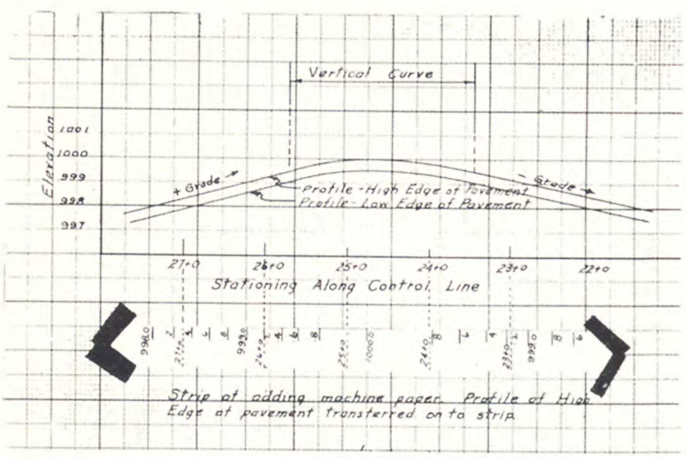

Fig. 5. Showing Method of Transferring Grade Information to Strip of Adding Machine Paper for Purposes of Contouring

Scotch tape was used to hold the strip of adding machine paper in place while taking off this information. The strip of adding machine paper was then laid on the plan, with stationing matching, and the points of every 0.2-foot change in elevation were easily transferred to their proper place on the plan. This was done for both the high and the low edge of pavement, and the lines or curves connecting these points determined the contouring. Intermediate points across the pavement were also plotted to produce a smooth and accurate contour. Since stationing was on the control line, on both plan and profile, transferring data in this manner to lines on plan other than control lines was a bit tricky. In this case it was necessary to project points of 0.2 foot contouring radially across pavement from control line on plan as, length around one edge of pavement would naturally be different from length of an opposite concentric edge. The Final Interchange Drawing was then complete, being completely tied in both horizontally and vertically.

Eleven Interchanges along the Turnpike were worked up in a manner as just described. For each Interchange there was (1) a Preliminary Drawing, (2) a Control Drawing, and (3) a Final Drawing, showing contouring. Separate grading drawings, giving ramp profiles, were drawn for the guidance of the contractors working on the grading and paving of the Interchanges.

Each Interchange was so located that approaching traffic could look down upon it and quickly see the general layout of the offbound ramp and the toll booth. The accelerating and decelerating lanes at each Interchange were 1200 feet long, contiguous and parallel to the Turnpike paving. Vehicles not leaving the Turnpike at an Interchange will not be inconvenienced by traffic leaving or approaching the Turnpike at the Interchange. The accelerating lanes are of ample length so that entering traffic will not enter the Turnpike until attaining the speed of the normal flow of traffic. Likewise decelerating lanes give the driver ample time to bring his vehicle to a full, safe stop at the toll booth. All Interchanges were designed with safety as a paramount factor, and insofar as possible they were made foolproof from a safety standpoint.

Comments by Professor Robert W. Van Houten, Assistant to the President, Newark College of Engineering:

The Pennsylvania Turnpike Commission was created by an act of the 1937 Legislature of the State of Pennsylvania and was given the power to "construct, operate, maintain and finance a turnpike from Middlesex to Irwin." The members of the Commission are Mr. Walter A. Jones, Chairman; Mr. Frank Bebout, Mr. Charles T. Carpenter, Mr. Thomas J. Evans, Mr. I. Lamont Hughes, Ex-Officio Member, Secretary of Highways, Pennsylvania, and Mr. John D. Faller, Secretary-Treasurer.

The first major obstacle confronting the Commission was the problem of financing the construction of the turnpike. A private syndicate was formed to purchase bonds, and the federal government, being convinced of the merits of the highway from the standpoint of national defense, agreed to assist in financing the project. A grant of $26,100,000.00 was approved by the Public Works Administration and the Reconstruction Finance Corporation agreed to purchase bonds from the Commission in an amount not to exceed $35,000,000.00. It is expected that all bond issues will be amortized by 1954 through the income received from tolls. The financial problems and numerous others with which the Commission was faced were all satisfactorily solved, and it is reasonable to assume that the highway will be completed and in operation by June 29, 1940, the date established by the 1937 Legislature for the completion of the turnpike.

Mr. Harvey W. Sarven, author of the article on "Interchange Design on the Pennsylvania Turnpike," was graduated from the Newark College of Engineering in June, 1937. After graduation he did drafting and title examination work for the New Jersey Realty Title Insurance Company of Newark, New Jersey, until February, 1939. He left this position to join the Special Highway Unit on Interchange and Tunnel Approach Design of the Pennsylvania Turnpike Commission in Harrisburg, Pensylvania. While with the Commission, Mr. Sarven worked under the direction of Mr. Charles M. Noble, Special Highway Engineer, who read and approved his article for publication. Mr. Sarven's work dealt with the layouts and the computations for the controls of the complex curvature which make up the various ramps of the Interchanges. Since September, 1939, Mr. Sarven has been employed by the United States Engineer's Office in Charleston, South Carolina, as Engineering Draftsman.

A DEMONSTRATION MODEL FOR RIGID FRAME THEORY

By WILLIAM S. LA LONDE, JR., S.B., M.S.

Professor in Civil Engineering, Newark College of Engineering

The model described in this article was developed from the desire to bring to the classroom a mechanical demonstration of the series of steps required to distribute the moments in a rigid frame in accordance with the Hardy Cross method of moment distribution. The model consists of a number of steel posts that are each fastened securely by a pair of screws to a piece of five-ply veneer board held in an upright position. Steel rings are set over the posts and may either turn easily about the posts or be clamped tightly to them by means of set screws. Spanning between the rings are rods of one-eighth inch drill steel (0.80% to 0.90% carbon) heat treated and giving a proportional limit over 85,000 pounds per sq. in., the ends of which fit without binding into reamed holes in the rings.

In operation the ring and post "sets" act either as "joints" or as restrained or rocker end conditions. In order not to complicate conditions this model was built for frames having no sidesway. The parts shown in Figure I are assembled in a frame as shown in Figure II with non-slip riders on the rods to which loads may be applied. As shown in Figure II, one 2-kilogram load is applied at the mid-point of span 1, and nine 200-gram loads are applied at the tenth-points of span 3. These latter loads are the equivalent of a uniform load of 2 kilograms on span 3. Figure III shows the loads applied to the frame with all joints locked against rotation, thus visualizing the first step in assuming the frame as a group of single span beams restrained at the ends. Figure IV shows joint 3 unlocked. The ring has rotated, and now members at the joint are carrying a moment. The joint is again locked, that is, fixed against further rotation. Figure V shows joint 2 unlocked, the second step in distributing the moments in the frame. Figure VI shows the moments entirely distributed in the frame, assuming that the bottom ends of the columns are fixed, and Figure VII shows the moments in the frame distributed, assuming that the rocker ends are at the base of the columns. Each joint may be unlocked and locked at will. With a load in span 3 only, a wave of distribution may be followed all the way across the model from joint 3 to joint 1 and back to joint 3.

Having served its purpose visually to introduce moment distribution to the students, the model was next used to illustrate the slope deflection equations. Pointers were inserted into holes in the rings, and arcs of a circle were graduated so that the pointers would read radians directly, each division on the arc being equal to one one-hundredth radian.

The model shown in Figure II was loaded in a series of tests with concentrated loads at the mid-points of the end spans (spans 1 and 3). It was found after trial that 300 gram initial loads with 200 gram increment loads up to a total of 1300 grams each, gave very consistent changes in angle at the joints.

By plotting the total rotation against the total applied load, and by drawing a straight line between the plotted points to be as near the mean of the plotted points as possible, the rate of rotation for a load of 1000 grams may be determined. Other amounts of load may be assumed to give proportional results. The loads may be placed on only one span at a time or on several spans at once, thus giving the student an opportunity to study both simple and complex distortions in the frame. The members at the far ends (points 1, 4, 5, and 6) were assumed unrestrained. However, it was recognized that the rings would produce some stiffening effect. Span 1 and the right column have lengths of 13.5 inches center to center of joints, but only about 10.25 inches clear between rings. Span 2 and the left column are 19.5 inches center to center of joints, and span 3, 25.5 inches. The diameter of the rods varies between .125 inches and .127 inches. Also, the modulus of elasticity of the materials was not known. To overcome this lack of information, certain calibration tests were made.

In a simply supported beam the end reaction of an M/EI loading will be equal to the slope at that end. Therefore, the model was disassembled, and a load was placed at the mid-point of each of spans 1, 2, and 3 acting in turn as simply supported beams. The load was increased as mentioned for the model, and the rotation at both ends was noted to be numerically the same. This does not mean that the pointers read the same numbers on the scales, but that the difference in the readings for a given increment of load was noted to be the same at both ends, with opposite signs. Thus CEI is equal to $PL^2/16\theta$. C is the constant that accounts for the added restraint given the beam by the ring, and also for irregularities in the cross section of the members. θ is the observed rotation in radians produced by a load P on a span whose length is L measured from center to center of joints. It was not considered necessary to separate the terms C, E, and I, for when they are divided by the length, L, of the member, the whole becomes the EK for that member of the model. It was first thought that all members of the same length would have the same EK value, but this was not the case, and the EK values of the columns had to be determined also.

The computed rotations for the joints in the frame shown in this article agree with the observed rotations very closely. However, on a percentage basis they may vary as much as 30 percent for small rotations at the foot of the columns (.015 radians and less) and as close as from 6 to 10 percent for the larger joint rotations (joints 1, 2, 3, 4), where all members of the same length are assumed to have the same EK values. When the EK value is carefully worked out for each member very little difference is obtained.

It is felt that the sensitivity of the model is adequate for quantitative measurments for use in the classroom where the primary object of the use of the model is to develop a tangible meaning for the various parts of the slope deflection equations and for the simple steps in applying the method of Moment Distribution.

A model could be constructed to illustrate sidesway in combination with joint rotation. Only such joints as represented fixed conditions at the ends of members would be fastened to the ply-board. All other joints would be free to move. In such a model the posts would be drilled to receive the members directly. A disc of metal carrying a graduated arc would be free to rotate around the posts. By means of straightedges or base lines running vertically and horizontally on the board, the horizontal and vertical displacements could be measured by the difference in coördinates of the joints. The metal discs could be oriented with the vertical at each reading, and thus the angle of rotation of the joints could be measured directly. The author regrets that in this last paragraph he cannot speak from experience, but such is the way with these models that they develop all too slowly as a by-product of our theoretical instruction. He, therefore, invites suggestions and discussions from those who are interested in the subject.

It would not do to conclude an article of this nature without giving a few of the small points that make model building interesting. All parts of the model were machined and used before it was decided to have them chromium plated. The rods increased in thickness at the ends, and all holes in the rings had to be reamed a little larger. This reaming apparently has made no difference in the action of the model. It is planned to redrill one hole in two of the rings to three-eighths inch diameter and make some pairs of three-eighths inch outside diameter sleeves. The inside diameter of each pair of sleeves would vary to accommodate different sizes of rods, and thus make it possible to vary the stiffness of one member without changing the length. Although the rods were heat treated and have considerable temper they receive a slight permanent deformation under repeated use which might call for recalibrating the members from time to time. At the start, oil was placed on the posts to insure easy turning of the rings, but this proved troublesome to locking the joints against rotation.

The College is indebted to the Bennett Insured Steel Treating Company, of Newark, for the heat treating work. The author is also indebted to Mr. August Reminger of the Mechanical Engineering Department Shop for working out the dimensions and making the joint sets; to Mr. Joseph Shefrin, a Junior student at the College and an assistant in the Drawing Department, for the drawings shown in Figure I; to Mr. Pompey Mainardi of the Department of Mathematics for taking the pictures shown herein; and to Professor H. N. Cummings of the Department of Civil Engineering for his suggestions.

Comments by Professor Harold N. Cummings, Professor in Civil Engineering,, in Charge of Department, Newark College of Engineering:

Prof. La Londe's model, as he says, was originally intended only for helping students visualize the progressive analysis by the Moment Distribution method. However, we found that by removing all but two bars, leaving for example only S2 and S3, the model could be very helpful in showing the derivation of the Three-Moment Equation, that is, the equation connecting the moments at joints 2, 3, and 4. I add this comment to indicate the flexibility of the design, and to suggest the further use of the model, by properly selecting parts of it, to illustrate many other of the various problems in "Structures" in which end-restraints, end-rotations, or beam deflections are involved.

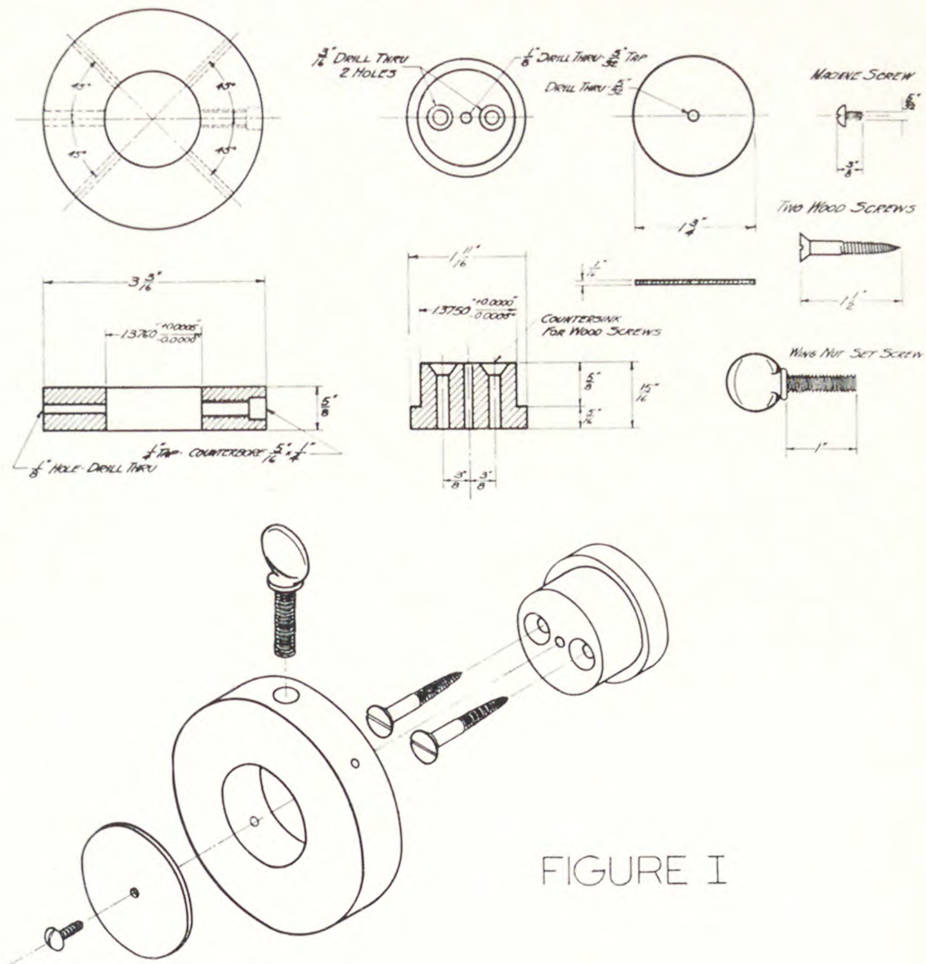

FIGURE I

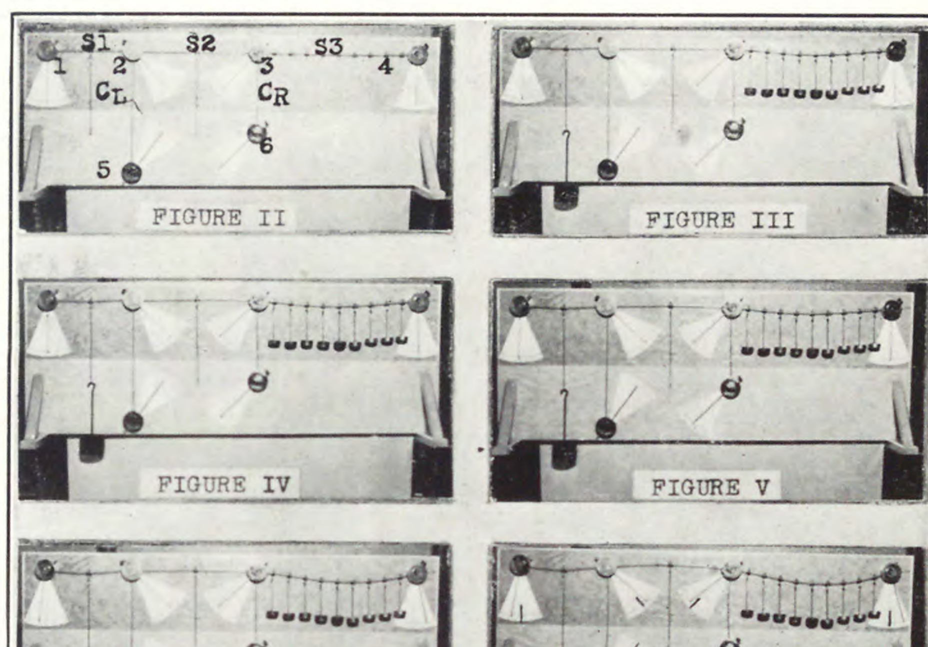

FIGURE II FIGURE III FIGURE IV FIGURE V FIGURE VI FIGURE VII

THE PURPOSE OF VISITORS' DAY

By Frank A. Grammer, A.B.

Associate Professor in English and in Charge of Department,
Newark College of Enginneering

It has always been the philosophy of the Administration of the College that traditions should not be acquired deliberately but must have their inception naturally and continue to grow in the same fashion. Certainly this is true of "Visitors' Day." Starting some fifteen years ago as Parents' Day, when several hundred people attended, it has outgrown its first appellation and has increased in the scope and elaborateness of displays as well as in the number who yearly attend. There were approximately two thousand visitors this year.

One might be led to the opinion that a definite effort has been made to build up Visitors' Day. Such is not the case. Rather it can be said that the increased stature of this annual open house is typical of the growth of the College itself. If to the perennial visitor the demonstrations and exhibits seemed more elaborate than usual, the change was due to the improved equipment which the College now possesses. Though occasionally parents and friends were amazed, mystified, yes even bewildered by some of the displays, they were impressed by the sincerity, earnestness, and understanding of student demonstrators and were able to compensate for their own frustration in the pride of knowing someone who "knew."

It would be superfluous to give a detailed account of the departmental exhibits, even granting that it would be possible to prevent the words beggaring the description. Due credit should be given the committee of the members of the Student Council that so ably managed the affair and who introduced the plan of conducted tours of groups of visitors. All the students acquitted themselves well—in the laboratories, the gymnasium, and in providing entertainment in the Commons. The non-academic as well as the academic staffs of the College personnel contributed much to the success of Visitors' Day, 1940.

Many, no doubt, came more because of a general interest in the College or the more intimate concern of learning how their offspring are being educated than because of their fascination for things technical. Many of the alumni returned not so much for what they might see as for whom they might meet. These motives are not less worthy and harmonize admirably with a broad conception of the meaning of Visitors' Day.

The Class of 1933 evidenced its interest in the College by the gift of a clock. The clock, presented by Mr. Van Zile, a member of the Class, was received by President Cullimore. It is to be hung in the new Weston Museum, which contains the collection bequeathed to the College by the late Dr. Edward Weston.

In the Chemical Laboratory (top)

Professor V. T. Stewart, in Charge of Chemical Department, explains the operation of distillation apparatus. Dean James A. Bradley, Associate Professor in Chemistry, is standing in the background.

In the Industrial Engineering Department (center)

The assembly of electric plugs as carried out in the micromotion laboratory in the Frank B. Gilbreth Room is demonstrated. The student acting as operator is seated at a special table designed for analysis work. On the table may be seen adjustable bins placed in a semicircle around the operator, and a micro-chronometer for measuring time to 1/2000 of a minute. At the right of the table and in the lower left foreground can be seen reflectors for high powered lights to illuminate the workplace for taking motion pictures. In the left foreground is the motion picture camera on its tripod. The pictures of operations taken in this manner can be analyzed to discover minute details in the methods of doing work.

In the Mechanical Laboratory (bottom)

Professor Paul E. Schweizer, Assistant Professor in Mechanical Engineering, explains a micro-photograph of a steel specimen. Visual microscopes and photo-micrographs are used in this Metallographic Laboratory.

NEW HORIZONS *of* SCIENCE

Graduate engineers and others who are interested in new electrical developments are invited to attend an unusual laboratory demonstration and lecture on new scientific products of the research laboratories. Dr. Phillips Thomas of the East Pittsburgh division of the Westinghouse Electric and Manufacturing Company will present some unique experiments with light, sound, and magnetism in Campbell Hall of the Newark College of Engineering on Tuesday, April 2, 1940, at 8 P. M. Dr. Thomas, who is on lecture tour in the East, will demonstrate a new light whose brilliancy is one-fifth that of the sun's surface brightness, new uses of untraviolet light in color control, and modulated light waves through a medium of water to play music. These and many other tools of science will be shown.

The tiny two-inch mercury vapor arc lamp containing a bead of mercury and a trace of argon gas produces one thousand watts by means of a minute mercury arc inside of a quartz tube. The tube is enclosed by a glass water jacket circulating cooling water. The new lamp can be used to advantage in photo work, searchlights, and therapeutic applications. The basic principles of commercial fluorescent lamps will be exhibited. By using chemicals to transform ultraviolet radiations to visible light, unusual color effects will be produced. The application of the new Sterilamp will be demonstrated by projecting on the screen through a high power microscope the dramatic effects of these sterilizing rays in killing bacteria. The Sterilamp is a recent development of the Westinghouse Lamp division Research Laboratories at Bloomfield, New Jersey. New applications of the use of the gyroscope in the control of rolling-mill operations, and the automatic aiming of giant searchlights on moving objects will be shown. By use of magnetism, Dr. Thomas will control vibrational energy with unusual effects. These are only a few of the many new developments coming out of the research laboratory in the past few years which will be shown in this laboratory demonstration by Dr. Thomas on April 2.

Dr. Phillips Thomas received his B.S. degree from Ohio State University in 1904. For two years he was test engineer with Western Electric Company, later receiving his Ph.D. degree from Princeton University after serving five years as instructor in that institution. Dr. Thomas joined Westinghouse Electric and Manufacturing Company the next year, where he was first engaged in the design of capacitors and insulation problems. Later he was transferred to the Research Laboratories, where he was occupied with numerous radio developments and allied problems. He invented the ultra-audible microphone and the glow-discharge microphone used by KDKA and KYW in 1923-1924, an important step in the perfection of radio broadcasting microphones. During recent years he has participated in the research and development of electronic and light sensitive devices of all kinds including many applications of what is popularly called "The Electric Eye." He has been instrumental in perfecting the art of insulating electrical apparatus and machinery. Dr. Thomas has made a number of contributions to scientific literature, and is a member of the American Institute of Electrical Engineers and of the American Physical Society.

(Reported by Clarence H. Stephans, B.S., Instructor in Electrical Engineering, Newark College of Engineering.)

THE STUDENT ENGINEERING SOCIETIES

The January meeting of the Student Branch of the American Institute of Chemical Engineers was held on the twenty-sixth of the month. Mr. H. E. Newell, Assistant Chief Engineer of the National Board of Fire Underwriters, talked on "Insurance and the Chemical Engineer." Mr. Newell pointed out how particularly well fitted an engineer is for certain types of work in the field of insurance. His talk was in the nature of a survey of the engineering aspects of fire insurance and the use of the testing laboratory in this work.

On February 16 Professor Louis C. Jordy of Drew University spoke on "Chemical Warfare." His talk was illustrated by personal reminiscences of the use of gases in the last war, their testing here, and their use in Europe. Dr. Jordy showed, among other exhibits, American and German gas masks and samples of toxic gases.

(Reported by Dean James A. Bradley.)

The fourth regular meeting of the Newark College of Engineering Student Chapter of the American Society of Civil Engineers was held on January 8 in the Gilbreth Room with 35 present.

Mr. Charles Gilman, Massey Concrete Products Corp., and Senior contact member of the chapter, gave an illustrated lecture on "Concrete Piles." Mr. Gilman told of concrete piles (precast) first being used at the start of the century in the West. The manufacturing of the piles, curing, rigs for handling the piles, and the use of piles in railroad and highway construction was all shown. The use of precast and made-in-place piles was developed as well as the question of depth of the pile, this last item being solved by the use of test borings. Following the lecture a discussion period was held.

The fifth regular meeting of the Newark College of Engineering Student Chapter of the American Society of Civil Engineers was held on February 6 in Room 208C with twenty-eight present.

Mr. Charles B. Ferris spoke on "The Organization Activities of the Army Engineer and the Three Components—Regular Army, National Guard, and Organized Reserves." The work of the engineer in times of peace and war was taken up with work on rivers and harbors as well as in flood control being described. In the regular army the engineer would have the rank of a Second Lieutenant with affiliation in the organized reserves leading to the position of a commissioned officer. The requirements of the national guard and organized reserves as regards to enlistment were explained. The assignments in the three engineering divisions in war times were described, combat engineers having charge of the advance construction work, general service engineers working in the rear on various tasks, and camouflage engineers instructing men in the use of deception. The values to be obtained from engineering duty in the army were many, service to your country being one, the experience gained under trying conditions, another, and the wide range of work, a third. Motion pictures depicting the duties of the combat engineer were shown.

The sixth regular meeting of the Newark College of Engineering Student Chapter of the American Society of Civil Engineers was held on March 4 in Room 30A with forty guests, faculty members, and chapter members present.

Mr. Dominick Paradiso, Senior Representative to the A. S. C. E. Metropolitan Section, told of the executive meeting to be held on Sunday, April 7, and also of the Spring Conference to be held at Cooper Union on April 6, the topics for discussion being "Foreign Service" and "Student Curricula."

It was voted to hold a picnic in preference to a banquet in May for the purpose of turning the gavel over to the incoming President.

Mr. Eugene MacDonald, of the firm of Brinkerhoff, Parsons, Klapp, and Douglass, spoke on "Job Hunting," making a comparison between seeking employment in New York and South America. Mr. MacDonald told of the chance to travel and of the money being spent in South America, stating that Americans get to like Panama after five years of living there in its agreeable climate, with salaries being about 25% more than on Civil Service in the States. The speaker commented on the large Public Works program being carried on in graft-free Venezuela, with American - trained engineers in charge.

Poor sanitary conditions, flavorless food, and lack of amusements were some of the items that offset the ideal conditions thought to be existing because of the high wages paid.

In a later discussion period the speaker gave these answers to a few of the many questions asked: the Foreign Service did not hurt the engineer's chances upon his return to the States; the first offer for the job-seeker was a round-trip ticket and a six months' contract; all types of engineers needed; the biggest difficulty is acclimating oneself to that sort of life.

The next regular meeting of the chapter will be held on April 1.

(Reported by John Wulfers, Recording Secretary.)

To broaden their aspect of the engineering field, the Student Branch, American Institute of Electrical Engineers, has invited speakers from fields other than Electrical Engineering to be its guests. Accordingly, a talk on safety standards and one on the mechanical features of the "topping turbine" were presented at recent regular meetings. In addition, inspection trips round out our current program.

Mr. D. Royer of the Ocean Accident and Guarantee Company brought to us the meaning of Safety in the operation of power plants. By the use of lantern slides, the effects of explosions and breakdowns due to neglect and lack of careful inspection were forcibly brought to our attention. Of interest to the group was the fact that college trained men are active in the field of inspection and in research on corrective measures.

At our latest meeting we had the pleasure of hearing Mr. H. Weisberg, Assistant Mechanical Engineer of the Public Service Electric & Gas Company, who is the author of several articles including "Essex Tops at 1250# and 950°F.," *Power*, January, 1939. His talk was on some of the mechanical features of the "topping" turbine installation at Essex. He explained that the application of this superimposed turbine uses steam at higher pressure and temperature and exhausts into the existing turbines at their rated steam pressure. This has resulted in increased capacity with a minimum capital outlay and a decreased fuel cost per kilowatt hour. The success of this installation is reflected by the current installation of duplicate equipment at Marion. Thus the utility company anticipates the new weekly peaks in electrical energy consumption.

Between its regular meetings the group made a survey trip to the WOR Master Control Board at 1440 Broadway, New York City, where, through the courtesy of Mr. J. Popelle, Chief Engineer, we were shown what it takes to put a radio program on the air. Mr. Scatterday, Engineer, took us from rehearsal, through timing, to monitoring control. In addition to actually getting the program on the networks, he showed how the program might be repeated by the method of phonograph transcription and Miller-film recording.

Lackawanna Rectifying Substation at Roseville was also visited by the students. Here the 12-phase mercury vapor rectifiers and their auxiliary equipment were inspected by the students.

The March 18 meeting has been set aside for the presentation of senior papers to select the one to be presented at the annual student convention. The following papers will be heard: "Vector Potentiometer," by R. E. Coleman; "High Frequency Q Measurements," by H. G. Elwell, Jr.; "Permeability Tuning," by J. Buonincontri; "Iontophoresis," by L. Fernandez.

It has been announced that at our meeting of April 2, the College has invited Dr. Phillips Thomas, Research Engineer, East Pittsburgh Division, Westinghouse Electric & Manufacturing Company, to speak. His lecture and demonstration will be on recent developments in the electrical field of electronics. This meeting will be of particular interest to our graduates and they are urged to be present, as Dr. Thomas will deliver only a few similar lectures in the East.

(Reported by C. H. Stephans, Counselor.)

STUDENT CHAPTER WINS AWARD THIRD TIME

The Newark College of Engineering Student Chapter of the American Society of Civil Engineers is reported by the Committee on Student Chapters as having excelled in conducting its affairs in an effective and meritorious manner during the academic year 1938-39.

In a letter to Professor W. S. LaLonde, who is the Faculty Adviser of the Student Chapter, Mr. D. H. Sawyer, the past President of the American Society of Civil Engineers, writes: "It gives me particular pleasure to note that this is the third year that the Committee on Student Chapters has recommended the Newark College of Engineering Chapter for commendation. This is a matter for justifiable pride on the part of everyone connected with the Chapter as it is on the part of the Society.

"Inasmuch as a Chapter's success can result only from ability, punctuality and diligence on the part of its officers and members, this year's record speaks well for the character of the organization and of the membership.

"I take pleasure in extending to the Chapter the felicitations of the Board of Direction and in sending you this letter of commendation."

For administrative purposes the 120 Student Chapters of the American Society of Civil Engineers were divided into four districts, of which the Northern comprised 30 Chapters; the Eastern, 30 Chapters; the Southern, 29 Chapters; and the Western, 31 Chapters.

In this district (the Eastern), Newark College of Engineering has won the award three times and Johns Hopkins University and New York University have won it twice each.

Inasmuch as the Chapter's success can be judged only through the annual report submitted to the American Society of Civil Engineers, special credit must go to Mr. P. Carlino, Recording Secretary and Senior at the Newark College of Engineering, for his work in writing such a splendid report.

PROFESSIONALITIES

James W. McEwan, B.S. in Civil Engineering, 1933, Newark College of Engineering, has been with the United States Fide'ity and Guaranty Company in New York City since 1936. He has recently been promoted to Assistant Supervising Engineer.

Mildred A. Preen, B.S. in Electrical Engineering, 1938, Newark College of Engineering, is now attending Columbia University, majoring in Public Law towards a M.S. degree.

John P. Sliwa, B.S. in Civil Engineering, 1939, Newark College of Engineering, is now an engineer with The Highway Corporation in Newark, New Jersey.

Bruce P. Domorski, B.S. in Civil Engineering, 1939, Newark College of Engineering, is now employed as a draftsman by McKiernan-Terry Corporation in Harrison, New Jersey.

WHAT OUR READERS SAY

To the Editor:

Please accept my thanks for the copy of NEWARK ENGINEERING NOTES which includes the article on "Repulsion Motor Calculations" by Professor Paul C. Shedd.

I am pleased to receive this first, because I am interested in the topic, and second, because I know Professor Shedd personally and am glad to see his work.

Very truly yours,
WALTER J. SLICHTER,
Professor of Electrical Engineering,
Columbia University

New York, N. Y., January 29, 1940.

To the Editor:

I would appreciate it very much if you would place my name on your mailing list to receive regularly the NEWARK ENGINEERING NOTES.

The two copies I read at a friend's house only made me thirst for more of this wonderful magazine.

Very truly yours,
KENNETH W. SCHULTHEIS

Arlington, N. J., February 17, 1940.

THE VECTOR IDEA IN TRIGONOMETRY

(Continued from page 6)

from which the other Pythagorean relations are readily obtained.

From equations (2) and (1), we have

$\sin^2 (\alpha - \beta) = 1 - \cos^2 (\alpha - \beta)$

$= 1 - [\cos\alpha \cos\beta + \sin\alpha \sin\beta]^2$

$= 1 - \cos^2\alpha \cos^2\beta - \sin^2\alpha \sin^2\beta - 2 \sin\alpha \cos\alpha \sin\beta \cos\beta$

$= 1 - (1 - \sin^2\alpha) \cos^2\beta - (1 - \cos^2\alpha) \sin^2\beta - 2 \sin\alpha \cos\alpha \sin\beta \cos\beta$

$= \sin^2\alpha \cos^2\beta - 2 \sin\alpha \cos\alpha \sin\beta \cos\beta + \cos^2\alpha \sin^2\beta$

plus a quantity $(1 - \cos^2\beta - \sin^2\beta)$ which vanishes. Thus

(3) $\sin (\alpha - \beta) = \sin\alpha \cos\beta - \cos\alpha \sin\beta$

which checks when β is taken as zero. If in (3) and (1) angle α is set equal to zero, we have

(4) $\sin (-\beta) = -\sin\beta$

(5) $\cos (-\beta) = \cos\beta$

Now upon replacing β by $(-\beta)$ in (1) and (3) there results

(6) $\cos (\alpha + \beta) = \cos\alpha \cos\beta - \sin\alpha \sin\beta$

(7) $\sin \alpha + \beta) = \sin\alpha \cos\beta + \cos\alpha \sin\beta$

The double angle and half-angle formulas, and the addition formula for tangents, may be obtained in the usual way.

It is, of course, well known that the useful relations for reducing functions of angles of the form

$$\frac{n\pi}{2} \pm \beta \qquad (n = \pm 1, 2, 3, \cdots)$$

may all be deduced from (1), (3), (6) and (7). For example, if in (6) one sets $\alpha = 270^\circ$, the result is

$\cos (270^\circ + \beta) = \sin\beta$

To the mathematician, the interesting feature of the foregoing treatment of analytic trigonometry is the fact that the complete theory is evolved from one identity (1) without reference to any theorem not directly deduced from it.

Conclusion

The foregoing analysis indicates how the study of trigonometry can be more closely integrated with the program of professional engineering development. Whether closer integration is regarded as desirable depends in part on whether one accepts the assumption, implicit in this paper, that the reason for being of the trigonometry course is to contribute to the professional training of the prospective engineer.

It is not unlikely that some of those who are responsible for the content of the trigonometry course will feel that the plan just outlined is not practicable. My own classroom experience indicates that the vector point of view is not intrinsically more difficult than any of the conventional approaches. I have however observed that those students who have had no previous training in trigonometry fare better than those who have had some instruction along conventional lines. That is to say, it is difficult for one who has learned the subject in the usual way to make the radical readjustment in his point of view called for in this paper. This may be true of teachers as well as students. The moral seems obvious: the training in trigonometry now being given to engineering students is probably ineffective as a preparation for professional studies, because a radical change in point of view is necessary before the relationship between what has been learned, and its application to technical problems, can be grasped.

Comments by Professor James H. Fithian, Head of Mathematics Department:

Dr. Baker advocates here an approach to trigonometry which differs widely from familiar, time-worn methods. It is difficult for those of us who learned the subject in the old way to divorce our minds from preconceived ideas so that we can comprehend the viewpoint of a student who learns of sine and cosine for the first time from the definition given in this article. But the increasing importance and usefulness of vector methods in engineering mathematics and mathematical physics lend justification to such a viewpoint, and promise an advantage to the student who has had such training. It wou'd be interesting to try this new approach with a group of entering freshmen who had not studied trigonometry previously.

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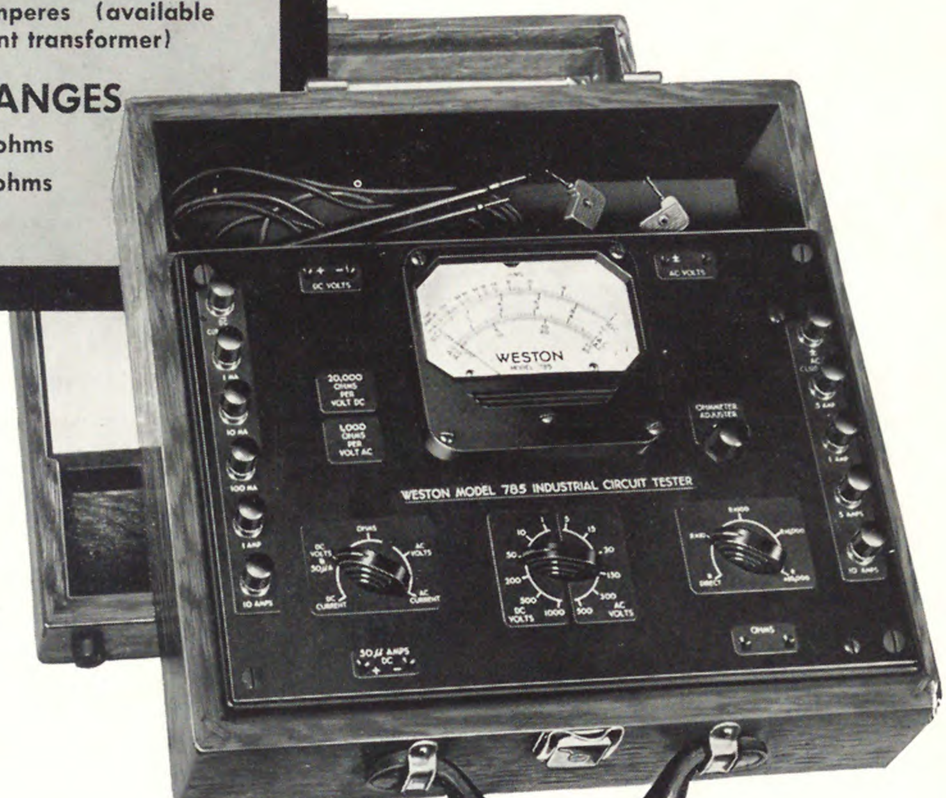

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