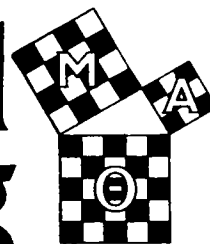


The Mathematical Log

VOLUME 25, NUMBER 1 -- OUR 25TH YEAR -- FALL 1980



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UNDERGROUND MATHEMATICS

Tunnels and Tunneling

by Dagmar Henney
George Washington University

The first tunnel acknowledged in history was under the Euphrates more than 4000 years ago. It is incredible to think that the next tunnel under water was not until the Thames Tunnel in England in 1842. This earliest tunnel connected the Royal Palace with temples in Babylon. The early Greeks had one of their best known tunnels on the island of Samos in the Aegaen, described by Herodotus. It was started through a mountain from both sides of the mountain through limestone rock with hand hammers and chisels, with few irregularities though apparently not meeting at the end.

In the time of Augustus a tunnel was built for carriages to reach the favorite resort area of the Emperor in Baiae through rocky hills, connecting Naples and Posilipo.

The Hadrian Aquaduct supplied the ancient city of Athens with fresh water from Mount Parnes during the Roman occupation of Greece. It was discovered and rediscovered and finally renovated by Americans in 1972, and is now serving as an essential part of the Athens water supply.

Up to this time, tunnels were done by hand, drilling holes with hammers, chisels and wedges, then heating the rock face with fire and dashing cold water on it to cause fracture. In other instances, vinegar was used to break up the rock instead of water.

Gunpowder was introduced probably in the construction of a canal in France. Holes were filled with explosives and fired to break out the pieces. With this milestone, tunneling made great progress continuing to the railroad era. Convenience added to the necessity of creating tunnels for shipments in coal mining.

The first railroad tunnel was built in France (St. Etienne), and at this same time

Brunel was struggling to complete the Thames Tunnel in England.

The Thames Tunnel project began in 1800 when there was no thought of shields. The essential idea of boring holes into the mountain and then lining that area was used. However, Brunel developed a cylindrical shield which consisted of a heavy steel plate fitting over the tunnel structure so that the front and back end could be wholly or partially closed. The shield was moved ahead by pressure of jacks pushing against the previously erected portion of the tunnel shell, like pushing a pole into mud. At the end of each forward movement the back portion of the shield still overlapped the end of the completed tunnel, providing an end within which the next ring of tunnel could be erected. Cast iron for lining was used at this time instead of brick. When completed, the Thames Tunnel was not used for 23 years. At long last it functioned as a railroad tunnel and was most useful.

Tunneling through the Alps was a great break-through in tunnels. The length alone of 8 mi. (13 km) through Mount Cenis was a challenge. Yet the ventilation was one of the greatest problems with the development of the steam engine. It seems ironic that when driving through a tunnel, people are most concerned about the countryside and scenery at the end of the tunnel, rather than the engineering which allowed them to pass in a few minutes through, say, 12 mi. (20 km) of mountainous terrain.

Subway tunnels were starting to be built in the 1800s. First the London subway system, the Paris Métro fashioned along the same lines as the London subway, Budapest, and then to America. The Moscow subway system, although built later, remains one of the most beautiful in the world--not a dark tunnel dusty and cold, but one which can be appreciated for its artwork of inlaid friezes lining the walls, colorful, massive, and eye-catching.

The uses of tunnels were wide and varied. Canals were being constructed in New Orleans for carrying flood waters; in Chicago under Lake Michigan to ensure safe

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The official publication of the National High School and Junior College Mathematics Club, Mu Alpha Theta, which is sponsored by the Mathematical Association of America and the National Council of Teachers of Mathematics. Address correspondence to: Mu Alpha Theta, 601 Elm Avenue, Room 423, The University of Oklahoma, Norman OK 73019.

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Secretary's Corner

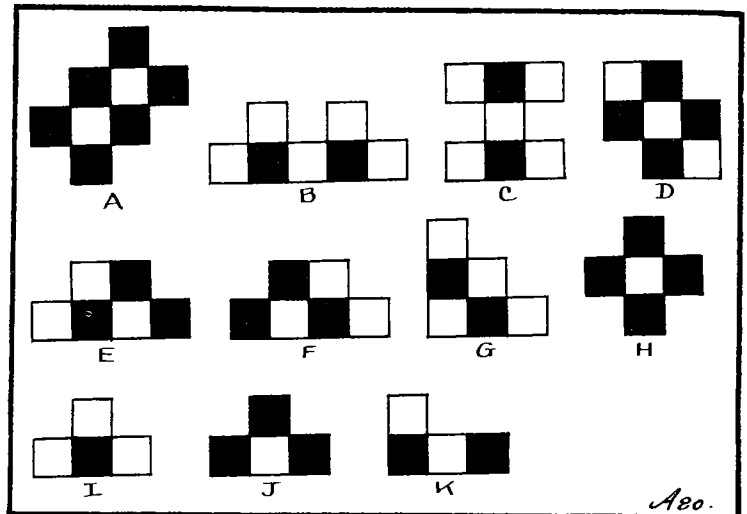
From Harold Huneke, Mu Alpha Theta Secretary-Treasurer, come the following items of information for chapters and individual members:

1979-80 YEAR "A GREAT ONE"

The past year was a great one for Mu Alpha Theta: 84 new chapters, 19 264 new members. Let's make 1980-81 even better.

INITIATION FEE CHANGE

Mu Alpha Theta chapters voted last Spring to change the one-time initiation fee (per member) from \$1 to \$2, the change to be effective August 1, 1980. A first-class mailing on this was sent out, but possibly we missed you.



ATLANTA CHALLENGE! The Editor's audiences at Mu Alpha Theta's 10th National Convention at Georgia Tech were left with this checkerboard challenge--an 11-piece dissection prepared especially for the event. The solution appears to be unique, and chapters are invited to share their findings. Reassemble the 11 pieces to form a perfect checkerboard, with alternating light and dark squares.

RETIRING EDITOR SAYS FAREWELL

Having completed her term as Editor of The Mathematical Log and taken on new duties within the National Council of Teachers of Mathematics, Dr. Betty Lichtenberg, University of South Florida, has penned the following as her farewell:

"It has been a great pleasure to be affiliated with Mu Alpha Theta and The Mathematical Log for the past few years.

"Contact with you all is one of the most rewarding experiences I've ever had. Thanks!

"Write letters to your new Editor!!"
--Betty Lichtenberg.

Sponsors Breakfast

A breakfast for Mu Alpha Theta sponsors will be held on Friday, April 24, 1981 in the Charles Lindberg Room, Sheraton Hotel, St. Louis, MO. The time will be 7 a.m. Reservations will be necessary, and should be made with the Mu Alpha Theta national office.

TUNNELS AND TUNNELING

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drinking water from the shoreline; also in Chicago, 60 mi. (100 km) of underground tunnels which few realize exist, carrying freight to the large department stores.

In the early 1900s, New York plants on Manhattan were becoming unable to cope with the rapidly growing demand for gas, and the congested area precluded the construction of large new plants. The alternative was a tunnel under the East River to pipe gas from Long Island into Manhattan.

When building the monumental Boulder Dam, rapid waters from the Colorado River were diverted for the period necessary for construction.

* * *

Methods used in tunnel construction have been, basically:

Open-cut method. A tunnel was constructed by excavating a trench to the desired depth, building a passageway in the trench, and refilling the space above the passageway.

Cut and cover. As pavement is taken up, usually at night, it is replaced by well-supported timber decks, under which the tunnel is constructed without disturbing life in the city.

Trench method. Used in tunneling under water. A trench of suitable size is dredged in the bed of a stream, and the bottom of the trench is properly leveled. Watertight sections of tube are then temporarily sealed at the ends by bulkheads which are floated into place and sunk to the bottom of the trench and the abutting ends of these sections joined together. Bulkheads or diaphragms are then finally removed to form a continuous passageway.

A lining is usually installed in a tunnel to prevent loose rock from falling, and is required to hold in place natural material surrounding the tunnel. The type and thickness of the lining will depend on the character of the rock.

* * *

Some tunneling records from the Guinness Book of Records:

Water supply tunnel: New York City-West Delaware, 1937-1945, 85 mi. (137 km).

Subway tunnel: London, 1939, 17 mi. (27 km).

Bridge-tunnel: Chesapeake Bay Bridge-Tunnel, Norfolk, Va., 1964, 17 mi. (27 km).

Canal tunnel: Rove Canal, between Marseille and Rhone River, 1912-1927, 4 mi. (6 km).

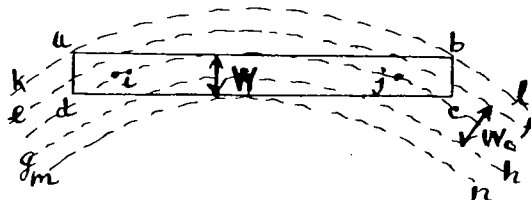
Railroad tunnel: Simplon II, Switzerland-Italy, through Alps, 12 mi. (19 km).

* * *

Several aspects of tunnel construction lend themselves to interesting mathematical treatment. Space permits development of but one.

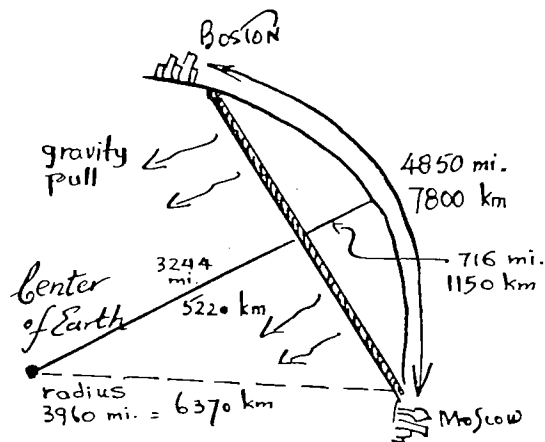
When a railroad tunnel is on a curve, the width of the section must be greater than that of a straight track. Where a railroad car (abcd) is on a curved track whose rails are (ef) and (gh)--where the center is illustrated by (i) and (j); its ends project farther outside the track when it swings around a curve than when traveling on a straight track. The corners (a) and (b) travel along the curve at (kl). The central part of the

car projects inside the track more than usual, therefore the path of the maximum projection is the curve (mn). In determining the path (mn) of the central part of the car, we must allow for tilting due to elevation of the outer rail. This elevation varies with the degree of curve and the higher speed of trains. The extra width of the tunnel on a curve must be at least equal to the difference between the required net width (W_c) and the width (W) of the car.



The distance between the outer rail (ef) and the path (kl) of the outside corners of the car is not the same distance as between the inner rail (gh) and the path (mn) of the inner face of the car. In order to keep the required width of tunnel as small as possible, a single curved track in a tunnel should be located so that the curve lying midway between the paths (kl) and (mn)--and not the center line of the track--will coincide with the center line of the tunnel. In the case of a double-track tunnel, the path (kl) for the outer track and the path (mn) for the inner track should be the same distance from the center line of the tunnel.

Reading into the history of tunnels will prove interesting, and the subject is rich in materials lending themselves to such mathematical interpretation. I want to conclude with the intriguing concept of a "global tunnel"--as once proposed by a free thinker named Cooper:



This tunnel (see diagram) would transport a passenger from any point on the earth in a straight line by means of a tunnel through the planet. The basis for "Cooper's theory" was that an object--a vehicle--dropped into a tunnel running (for instance) between Boston and Moscow would accelerate steadily during the first half of the trip to a speed which would produce the kinetic energy to "coast up" the other half against the pull of gravity . . . and reach any location in exactly 42 minutes!

dia **Log** ue

with the editor

DON ALLEN, THE LOG'S NEW EDITOR, HAS BEEN A FRIEND OF MU ALPHA THETA SINCE ITS EARLIEST DAYS. HE FOUNDED THE FIRST CANADIAN CHAPTER AT NORTHMOUNT HIGH SCHOOL, MONTREAL, IN 1960. MATHEMATICS CLUB SPONSOR AT NOVA SCOTIA TEACHERS COLLEGE SINCE 1969. DON WAS A PRINCIPAL SPEAKER AT MU ALPHA THETA'S 8TH NATIONAL CONVENTION IN STEVENS POINT, WI. DON'S HOBBY INTERESTS INCLUDE RECREATIONAL MATHEMATICS AND MONETARY HISTORY. HIS POSTGRADUATE DEGREES WERE EARNED AT UNIVERSITY OF SANTA CLARA, CALIFORNIA, AND RUTGERS UNIVERSITY, NEW JERSEY.

Our Georgia convention was outstanding! Pamela Drummond, general chairman, and Carol Wyndelts, program chairman, and Mu Alpha Theta students at Walton High School earned our greatest admiration for their efforts in planning and organization--and all came off exactly as planned. Now our sights are on California in 1981. At the Governing Council meeting in Atlanta, Fred Hansen offered an exciting preliminary report. The Log will have details next issue.

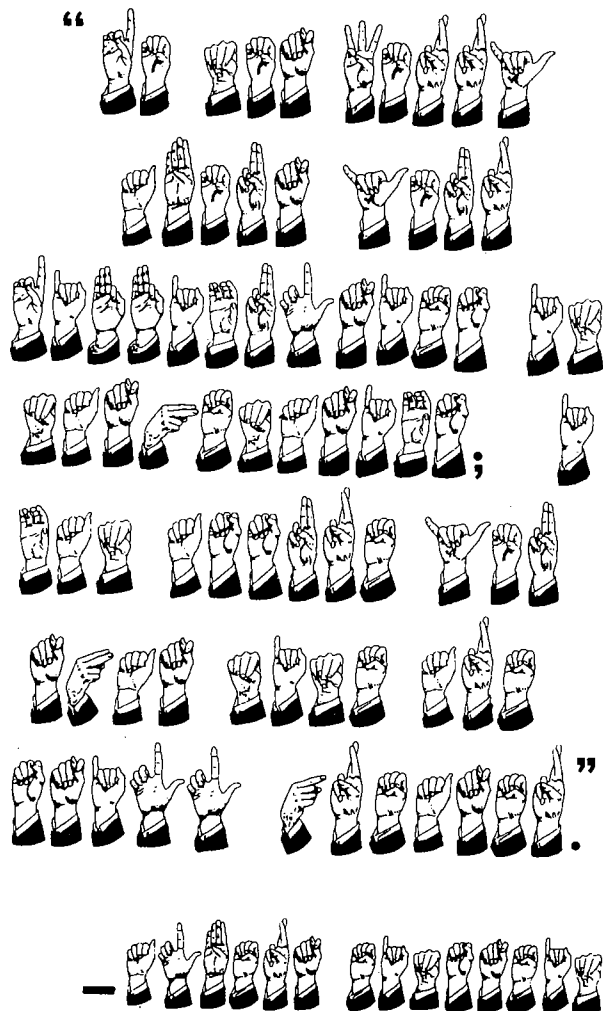
A special welcome, this first issue, to Mu Alpha Theta and to The Mathematical Log, to our perhaps 20 000 new members and to the thousands of others who are back with us for another year. The Log, to say the obvious, is your journal, it goes to every chapter. Use the Log. Share your good ideas for chapter programs. Tell your discoveries. Tell about worthwhile articles and books. Every chapter should be on the lookout for new ideas! Our own chapter opened its year with a presentation on the history of pi. Several "field trips" are in the planning stage.

Let's hear from you.

IRISH CATS DULY ANNIHILATED

"Annihilation," our transposition cypher in the Spring 1980 Log yields fairly readily once the significance of "gremlin," its 7-letter "codeword," is understood. One rewrites the "message" in rows of letters, 7 letters long. Resulting columns are headed with the letters of "gremlin," in alphabetical order: EGILMNR. Columns then are rearranged so that the letters spell GREMLIN. The thus reshuffled letters directly read off a charmingly nasty nursery classic, "There were two cats of Kilkenny . . ." According to solver Lynne Hannah, La Crescenta, CA, this particular gremlin "took . . . a while to unravel."

RELATIVITY



Aso.

RELATIVITY. The finger positions of "signing" comprise, in themselves, an elegant "code." Readers with a flair for ciphering may wish to direct their talents to the retrieval of a provocative quotation (above).

"MISSPELLED" NOT MISSPELLED

No, "misspelled" was not the misspelled word in "A Wit-Twisting Arithmetical Apptitude (sic) Test,"--"Apptitude" was, as numerous readers of the Winter 1980 Log were ready to point out. Those who wrote included Victoria Bychok, La Canada, CA; Holly Gwynn, Ft. Sta., VA; Laura Radic, Chicago, IL; Ray Stephens, Lenoir City, TN; Song Tan, Miami, FL.