A Meccano Planimeter

Determining Areas of Drawings by Mechanical Means

By H. F. Lane

A PLANIMETER is an instrument for determining by mechanical means the area of any figure, whether regular or irregular. Given certain principal dimensions, the area of a regular figure, such as a square, circle, triangle, etc., may readily be calculated from formulæ. There are other figures less regular than these for the graph, or outline, of which, an algebraic equation can be determined, and the area obtained by integration. But beyond these again are completely irregular figures, such as those shown in Figs. 1 and 2. Should the area of such a figure be required, it can be determined in the following three ways :—

(1) Graphical. Either by drawing the lines in on the paper or by placing on top of the paper a transparent sheet so ruled, we cover the figure with a multitude of tiny equal squares, the area of each square being some definite fraction of the scale in which the result is required, and then count up the squares (see Fig. 1). No error need result so long as we are dealing in whole squares, but when we come to the outer edges of the figure we shall find some of the squares incomplete, because cut off by the boundary line of the area (Fig. 3). Here each partial square must be considered on its own merits, and a search made round the edge of the figure for a second partial square of such a shape that the portion inside the area of the second square, added to the portion inside the area of the first square, will together equal a complete square, and so be included in our computation of the area. For example, the small portion B added to A makes a complete square.

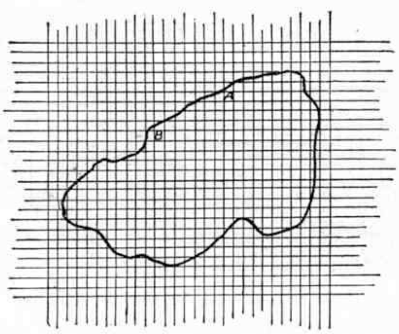

Fig. 1. Graphical method of measuring areas

To avoid counting a square twice or omitting it altogether, it is usual to shade, dot, or mark in some fashion, each square or partial square as we include it. This method of obtaining the area of the figure is very laborious, and the accuracy of the result obtained depends, obviously, on our "eye" for estimating the various pairs of complementary portions to complete the broken squares.

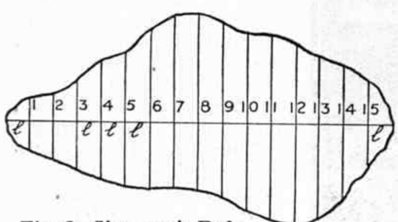

Fig. 2. Simpson's Rule

(2) By Calculation. In this method we find the length of the figure by drawing inside the area, and bounded by the edges of the area, the longest straight line possible (Fig. 2). We then divide this line into an even number of small equal parts, and draw through each division a line at right angles to the length of the figure. The additional lines so obtained are called "ordinates" and again are bounded by the edges of the area. Let l be the width of each small division, i.e., the distance separating each pair of ordinates. Add together the lengths of the two extreme, or outside, ordinates (1 and 15), and call the result A. Add together the remaining odd ordinates (3, 5, 7, etc.) and call the result B, and then the even ordinates (2, 4, 6, etc.), calling the result C. Then, supposing we have measured the various lengths in inches and decimals of an inch, we have :—Area of figure in square inches =

$$(A+2b+4c)\frac{l}{3}$$

This is known as Simpson's Rule, and again must be regarded as an approximation only, because if we have not a sufficient number of ordinates, we do not allow sufficiently for the irregularities of the figure, because each ordinate will have too large a relative value. On the other hand, although theoretically the equation only ceases to be an approximation and becomes perfectly true when the number is infinite, the more we increase the number of ordinates and decrease l, the more do we introduce personal error due to faulty measurement.

(3) By Mechanical Means. By the aid of an instrument termed the planimeter, the result can be arrived at with more accuracy and very much more rapidly, since all we have to do is to guide the pointer of the instrument carefully round the boundary line of the area, and read off the result on the recording apparatus.

There are several types of instrument designed for this purpose, some of them extremely complicated and able to perform a variety of functions, but the one in common use is Amsler's Polar Planimeter. It is on this principle that the Meccano model described below has been constructed.

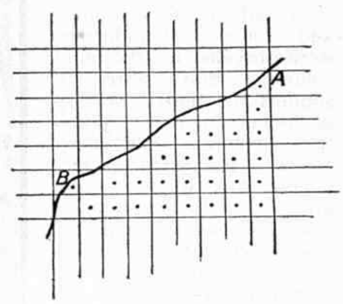

Fig. 3. Enlargement of AB in Fig. 1

The Theory of the Instrument

The instrument consists in its essential features of two bars PX, XT, (Fig. 5) hinged together at the point X. One end of the arm PX pivots about the fixed point P in the paper, and the end T of the bar XT has a tracing point secured to it. This tracer T is traversed round the entire outside edge or perimeter of the figure, the area of which it is desired to find.

The bar XT carries a wheel W that is sometimes rotated by the motion of T (when motion is perpendicular to XT), sometimes slid sideways without revolving (when motion is parallel to XT), and at other times undergoing a combination of both movements (at any other angle). As the wheel undergoes these various movements, it is always turning first in one direction and then in the other. When it has completed the whole perimeter of the figure, however, and returned to the point at which it started, it will be found that the wheel has rolled more in one direction than the other, and it is this difference in travel that measures the area of the figure, according to some predetermined scale.

It is not proposed to go too deeply into the mathematical considerations of the planimeter, but in the simple figure MNOQ (Fig. 5) it may readily be seen that the wheel records a definite sector MNX whilst rolling from M to N with X remaining stationary. The area of MNX is dependent entirely on the arc MN—since XM and XN are fixed lengths—and may therefore be recorded by the wheel. In this broad and approximate demonstration of the principle of the planimeter, we will disregard the slight roll of the wheel in moving from N to O. This roll of the wheel is very much less than the distance NN_2 (obtained by drawing ON_2 parallel to QM), because the point X takes up a new position X_2 as the bar XT moves from N to O, which counteracts the effect of the distance NN_2.

In moving from O to Q, we roll back again a certain amount of the roll of the wheel already recorded, but as in this figure the arc OQ is shorter than the arc MN, a diminished reading still remains. Also disregarding the second slight roll as the tracer moves from Q to M and still speaking approximately, we have recorded the area MNX less the area OQX_2, and the difference between the two is the required area MNOQ.

It must again be insisted that the above explanation is a non-mathematical approximation; the small rolls occurring while moving from N to O and from Q to M do affect the result and it is because they do so and further entail a movement of X, that the instrument is accurate for any figure, however irregular.

It will be noted that the point P lies outside the area. It is not proposed to mention the added complications entailed when the figure is so large that P must be placed inside the area.

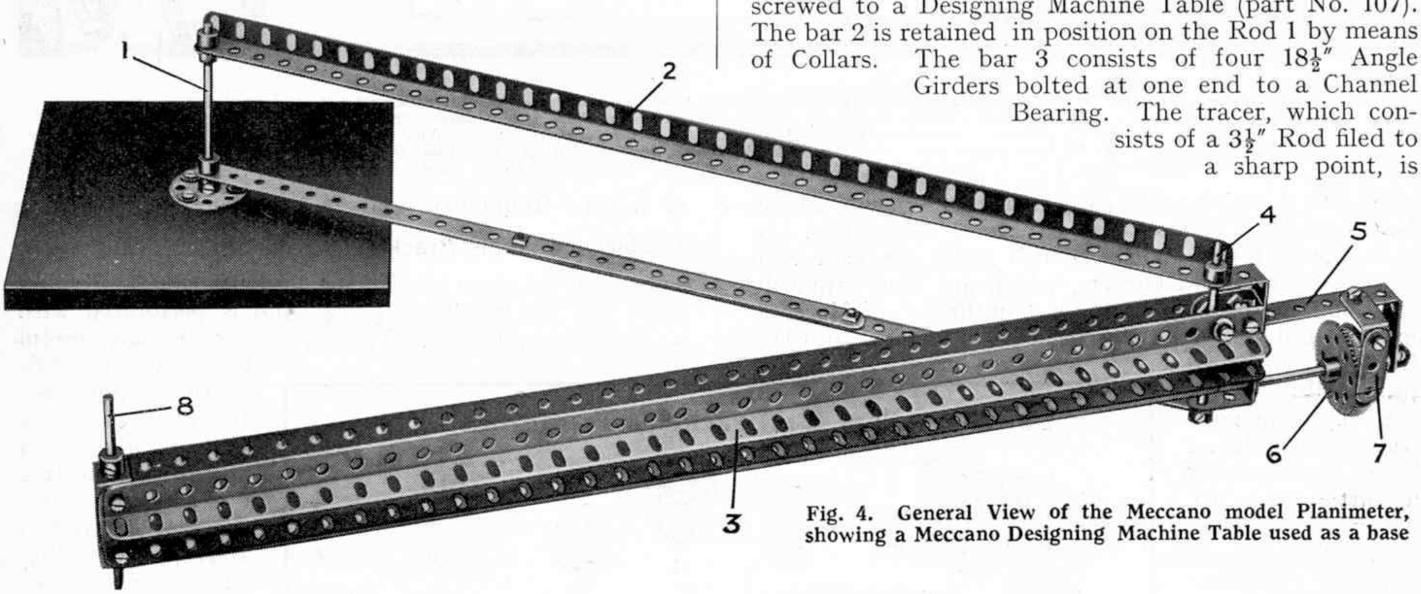

Fig. 4. **General View of the Meccano model Planimeter, showing a Meccano Designing Machine Table used as a base**

The Construction of the Model

As will be seen from Fig. 4 the construction of the model is very simple. The point P in Fig. 5 is represented by a 3½" Rod 1 that is held in a Bush Wheel screwed to a Designing Machine Table (part No. 107). The bar 2 is retained in position on the Rod 1 by means of Collars. The bar 3 consists of four 18½" Angle Girders bolted at one end to a Channel Bearing. The tracer, which consists of a 3½" Rod filed to a sharp point, is held in the boss of a Fork Piece secured to the upper pair of Angle Girders, and its lower end is passed through the centre hole of a Double Bracket that is secured to the lower pair of Girders. The two pairs of Angle Girders are spaced the correct distance apart at this end by 1½" Strips.

On the ½" side of the Channel Bearing, 2½"×1" and 2½"×1½" Double Angle Strips are bolted as indicated in the illustration, the former being used to connect the bar 2 to the tracing arm 3.

The wheel 6 consists of a 57-teeth Gear and a Flanged Wheel secured together on a 3" Rod that is journalled freely in the bottom hole of the Channel Bearing and in the end of the 2½"×1½" Double Angle Strip. A strip of paper is stuck round the circumference of the Flanged Wheel, and this Strip is marked off into 10 equal main divisions, each of which is further divided into ten subdivisions, making in all 100 divisions of the circumference of the Flanged Wheel. The main divisions should be numbered 0 to 9. The 1½" Strip 7 serves as a sighting piece with which to read the graduations on the Flanged Wheel, the graduations being viewed through the bottom hole of the Strip. In order to lessen the possibility of error a fine silk thread, termed a "spider line," should be glued across the hole in the Strip 7 so as to indicate the exact

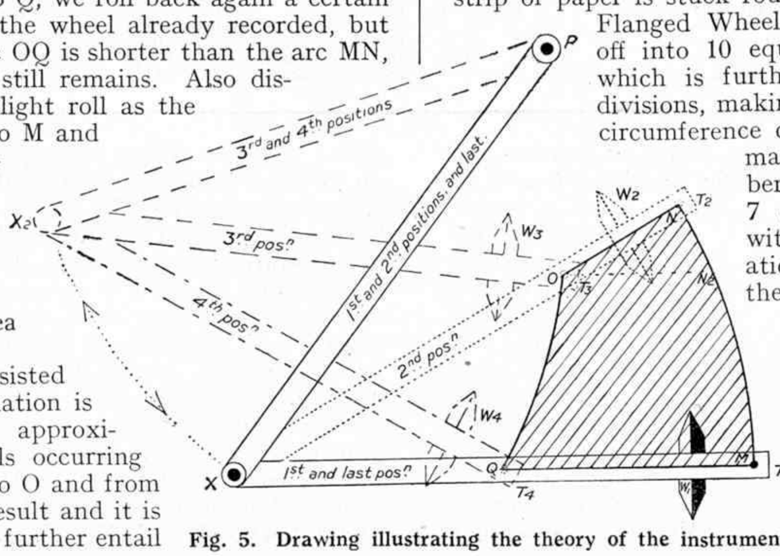

Fig. 5. **Drawing illustrating the theory of the instrument**

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Loading a Ton of Coal per Second

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belt while the main belt runs faster than the feeders so that there is never any danger of flooding either the main or the shuttle belts. The master control of the whole pier is located in the Superintendent's office.

Each of the four loading piers is equipped with a Lane-Galloway mechanical trimming machine. This machine eliminates completely the necessity for manual labour in connection with the loading of coal into vessels and has very considerably increased the operating efficiency of the pier.

In order to maintain the pier's operation in wintry weather, thawing sheds were built to cover the tracks leading to the car dumpers. These sheds have a capacity of 22 cars and a temperature of 180 degrees applied for 30 minutes thaws the coal sufficiently to allow it to free itself.

As stated in the second paragraph, the Curtis Bay Coal Pier periodically sets up a new record for the fast loading of coal into vessels. The present record in this respect was achieved on 13th April, 1926, when, by means of the plant, the S.S. "*Lemuel Burrows*," was loaded with 11,353 tons of coal in 3 hrs. 1 min.—an average of 3,763 tons per hour, or just over one ton per second! The record for volume of traffic handled at the pier during one week was set up in 1920 when the total of 182,000 tons of coal was attained by the close of the first week in November. These figures convey some idea of the immense capabilities of the plant.

The machines have been in constant use since they were erected 12 years ago and to-day they are as efficient as when first operated. Their great strength is further demonstrated by the way in which they successfully cope with any foreign material that accidentally enters the chute with the coal. Sometimes these undesirable objects are of such size and shape as to test severely the power of the plant. On one occasion a piece of iron, 3 ft. in length by 2 ft. in width, and about 500 lb. in weight, passed through the machines without causing any damage. In two other instances, large pieces of stone weighing 500 lb. and 600 lb. respectively, passed in with the coal and were delivered without any injury to the plant.

Meccano Planimeter

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centre line.

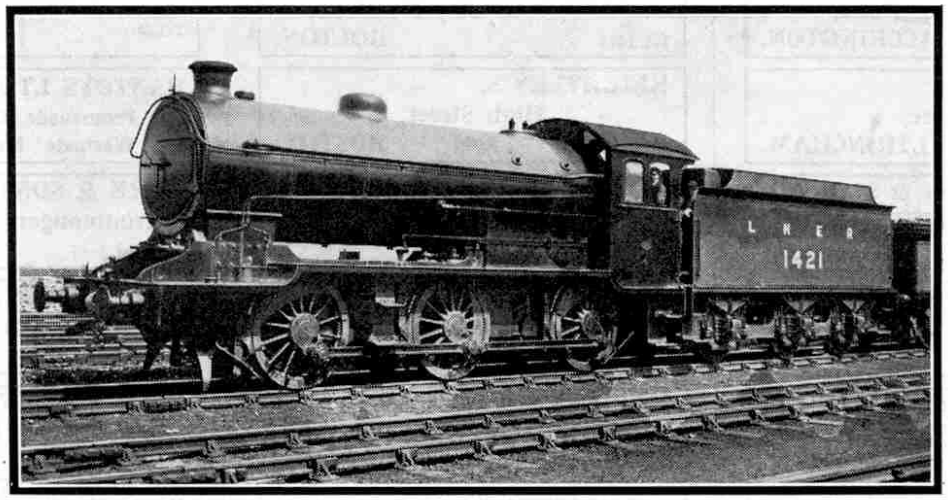
As already explained, the tracer 8 must be run round the perimeter of the figure and the number of divisions noted on the Flanged Wheel. The latter should be at zero to start with, of course.

It is impossible in this article to give the correct calibrations of the dial so that areas may be read off from it direct, for any particular machine will have a different scale as the result of slight variations in the exact relative position of the wheel. Each constructor therefore should calibrate his own instrument. The best way to do this is to draw squares or other simple figures, the areas of which have been calculated previously, so that by comparing the reading on the wheel 6 with each calculated area a table may be prepared, which should be somewhat as follows:—

Area of figure	Reading on Wheel
36 square ins.	4.2
16 square ins.	1.8
9 square ins.	1.
61	7.0

Dividing 61 by 7 we get approximately 8.7, which is the value in square inches of one main division. Each of the sub-divisions will have 1/10th of this value, of course, namely .87 square inches. Knowing the values of the scale, it is now a perfectly simple matter to find the area of any figure, however irregular.

To obtain the best results from the instrument, it should be placed on a good smooth surface drawing paper, so that the wheel 6 may roll quite smoothly and easily.



This photograph, by our reader R. D. Stephen, shows a L.N.E.R. 0-6-0 locomotive of the J.38 class. It is No. 1421 and was built in 1926, to the design of Mr. H. N. Gresley, Chief Mechanical Engineer of the L.N.E.R.

Conquest of the Air

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including three coastguards from the Kill Devil life-saving station, turned up to witness the event. Both of the brothers were eager to win the distinction of piloting the power-driven machine on its first flight and they settled the matter by tossing a coin. Orville won the toss, and climbing into the pilot's seat he started the engine. With a roar the aeroplane moved slowly forward, Wilbur keeping pace with it until it ascended into the air. The machine rose to an altitude of 120 ft. and remained aloft for only 12 seconds, but it proved that heavier-than-air machines capable of carrying a person on board could be successfully flown.

Three further trips were carried out that day, the last being of 59 seconds duration and covering a distance of 852 ft. All the four flights on 17th December were carried out against a 20 m.p.h. wind, but in every case a safe landing was effected. Shortly after the last flight, and before the aeroplane could be returned to its hangar, a sudden gust of wind overturned it and damaged it seriously.

From 1904 until 1908 the Wright brothers continued to experiment with power-driven machines, continually effecting minor improvements as the need of these became realised. In 1908 they visited France, and this visit and the work of the French airmen with whom they then came in contact will be dealt with in the next article in this series.

Largest Underground Tube Railway Station

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has been adopted at the new station, but the general effect is none the less pleasing and harmonious. The floor of the booking hall is paved with large white tiles, while the ceiling, of white fibrous plaster, is divided into rectangular coffers. Showcases with bronze framework, and frieze and skirting of Travertine marble, are ranged along the boundary walls on the east, west and north, while the telephone cabinets on the south are of polished teak. The booking office, on the west side of the hall, is also of Travertine marble and bronze, while the patent ticket machines that are to be installed later will be encased in similar marble, so that the harmony of the design and colour scheme may be preserved. The walls of the lower hall are faced with silver-gray tiles, while the lighting is by means of concealed lamps. The arches of the escalator tunnels have been decorated in matt white distemper to assist illumination, which is by means of lamps mounted on bronze pedestals, set at intervals along the balustrades.

Automatic ticket machines are an important feature of the new station. For the time being, the standard electric type, delivering pre-printed tickets are being used, but these will be replaced at an early date by a group of A.E.G. special ticket printing and delivering machines. The first batch of machines to be installed will number 26, and will be arranged so that they form portals to the passenger circulating area of the booking hall. They will include two machines for issuing 1d. tickets, two for 1½d., eight each for 2d. and 3d., four for 4d., one for 5d., and one for 6d. Tickets of greater value or of a special character will be obtained at an auxilary booking office, equipped with three A.E.G. ticket printing and issuing machines.

An interesting feature of the booking hall is a set of six train recording clocks. Each of these clocks automatically records the working of the service of one of the London Underground Railways.

Sets of similar clocks are installed at the Company's head office, in the traffic controllers' offices, at Westminster Station on the District Railway, and in the various signal boxes. We hope to publish a description and illustration of these remarkable clocks in an early issue.