

feel that the high school student should be given during his third and fourth years problems to be treated from the standpoint of the calculus. It seems to me that problems involving questions of variation and functionality are just the ones needed to lay the foundation of such work.

A very large amount of mathematical material presented to our high school people at the present time is made up of conundrums and blind-alley problems. It is but a little more valuable for developing mathematical ability and power in our boys and girls than saw-dust as a food for producing strength in horses.

Let us sift out the saw-dust from our mathematical courses and substitute in its stead a nutritious and wholesome food.

HOW TO DRAW A STRAIGHT LINE.

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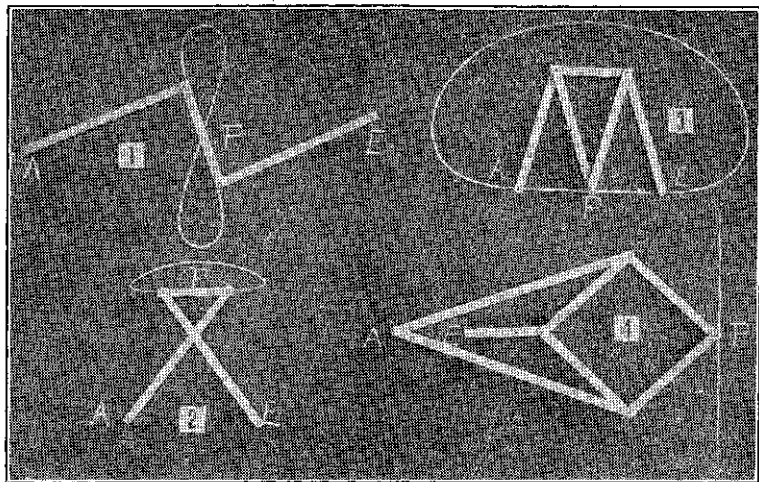
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To draw a straight line as an original exercise seems, at first thought, to be an exceedingly simple thing for a mechanic or mathematician. The circle, ellipse, and other well known curves which appear much more difficult can be readily described with simple and familiar apparatus. But how would you proceed to originate a straight line? Not by aid of straight-edge or ruler, for this presupposes a solution which you would thus simply copy—a mere begging of the question. To describe a circle with a compass is an original construction but to use a circular cut-out and trace around its circumference would be assuming that which is required.

This article describes several ways by which a straight line may be drawn as an original exercise by means of link motion or linkages. Aided by the models shown in the reproduced photographs the problem becomes a fascinating study of elementary mechanics.

Models large enough for demonstration purposes are very readily constructed from thin strips of wood fastened together with small screws and mounted on a blackboard or other smooth surface. A piece of crayon or lead pencil is used as a tracer and is fastened in the indicated position by fitting it in a small hole bored through the frame to receive it. For individual study smaller models made of strips of stiff cardboard and fastened together with shoemaker's eyelets are very satisfactory. The model should be fastened to a drawing board with thumb tacks over a sheet of paper on which a permanent record may be kept.

In the accompanying drawings, A and E represent pivots or screws with which the model is fastened to the baseboard and about which it rotates. P is the pencil or tracer.



Begin the study of how to draw a straight line with model No. 1. This shows, in its simplest form, a link motion well known to mechanics and engineers, Watt's parallel motion, invented by James Watts in 1784. If the long arms are of equal length and the distance between the pivots A and E is such that when the long arms are parallel the middle link is perpendicular to them, the tracer, which is located at the center of the middle link, will describe an approximate straight line if the apparatus is rotated a small amount. Move the tracer to its extreme positions and a figure eight shaped curve will be the result.

The line described by Watts' apparatus is sufficiently accurate for many purposes—most beam engines employ the device—but it will not solve the problem.

Model No. 2 has two radial bars each 10 in. long and a middle link 8 in. long which carries the tracer at its middle point. The distance between the pivots is 16 in. and between these two points the tracer describes an approximate straight line. If the distance is longer than this a peculiar curved line is traced.

Figure No. 3 gives a closer approximation to a straight line. The four upright links are of equal length and the horizontal link is equal to one half the distance between the fixed points. The path described by the tracer as it moves between A and E is apparently a straight line, but when it passes these limits a peculiar shaped closed curve will result.

But all of these and similar devices fail to describe an accurate straight line. It has been demonstrated that such a line can not be drawn with three links. The solution can be accomplished with five, seven, and other odd numbers of links. An odd number of links must be used to describe definite curves.

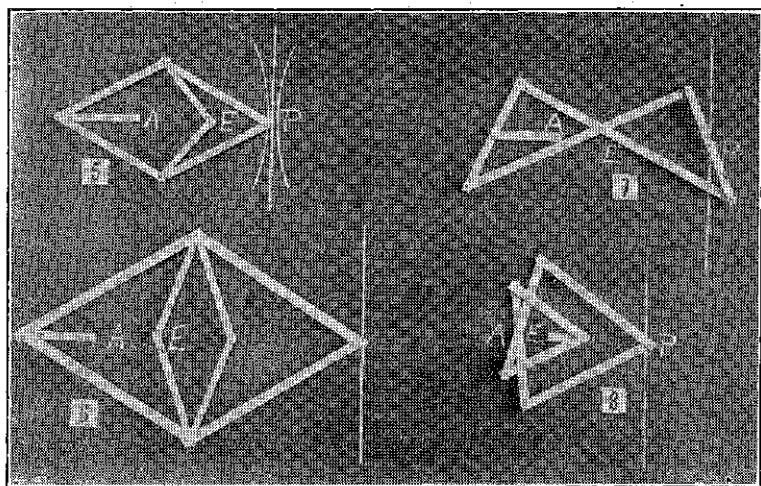
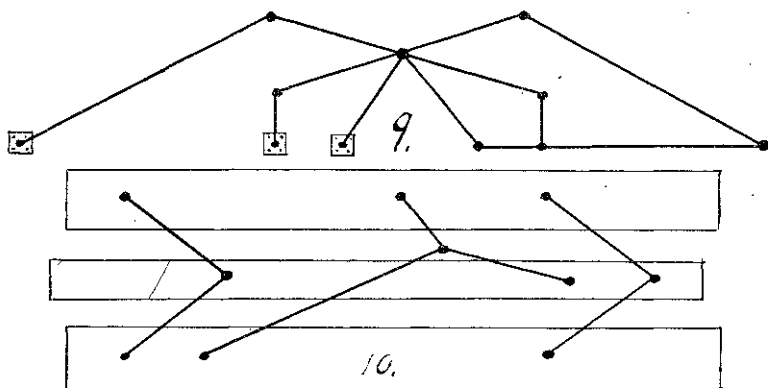


Figure 4 shows a seven-link device of great theoretical and historical interest as well as of considerable practical value. It is the first known apparatus by which an accurate straight line was drawn without the illogical expedient of copying some other, supposedly, straight line. It consists of two long links, equal in length and pivoted together at one end, the other extremities of which are joined to the opposite vertices of a rhombus composed of four equal but shorter links. If an extra link, EF , equal to one half the distance AF be added to this so-called cell, as shown in the drawing, and A and E be fixed points, a pencil fastened at P will trace an exact straight line as the cell is rotated on its axes.

With a working model before you this forms a unique experiment which never fails to attract and interest all who see it. It suggests other possible solutions and modifications and opens a wide field to the ambitious investigator. For example, what will be the effect if the extra link EF should be made a little shorter or longer than half AF ? Try it for yourself and you will be surprised to obtain arcs of two extremely large circles, one with the convex, the other with the concave side toward E . This suggests the possibility of constructing a drafting instru-

ment based on this seven-linked device for use wherever arcs of very large circles are required. The free end of the extra link should be mounted on a sliding pivot for quick adjustments.

Figure 7 shows a five-link system which will also describe an accurate straight line. This linkage goes through some remarkable contortions as it rotates about the two pivots but through it all the tracer follows unerringly the straight line path. A remarkable property of this model is that the middle points of the four links always lie in a straight line. Other linkages which can be used in describing a straight line are shown in figures 5, 6, and 8. The first of these may be adjusted in two and the second in four different ways by changing the point of attachment of the extra link and the fixed points.



It is often necessary to have a whole beam, instead of a single point, move so that all points in it move in a straight line as, for example, the slide rest in lathes, traversing tables, punches and drills. This can be accomplished by various combinations of linkages. In figure 9 the horizontal link moves to and fro as if sliding on a rigid horizontal support. Figure 10 represents a double horizontal ruler so constructed that if the lower ruler is held in a horizontal position the top ruler can be moved vertically up and down without any lateral movement whatever.

In addition to the uses already mentioned these models are very suggestive scientific toys for the mechanically minded boy. By changing the position of the tracer and varying the length of the links and the distance between the fixed points a series of strange and interesting results will be developed. Complicated curves can be obtained with the device used to illustrate Watts' parallel motion by moving the position of the tracer from

one end of the middle link to the other, an inch at a time, and tracing one complete, double-looped figure in each position. Sometimes a difference of half an inch in one dimension produces remarkable transformations in the figure obtained. By actual demonstration these models properly explained and presented have proved to be both entertaining and instructive to the casual observer and even to small audiences. They possess the peculiar merit of urging one on to make original research for his own enjoyment and satisfaction.

AN EXPERIMENT IN BIOLOGY BY A HIGH SCHOOL PUPIL OF COLUMBUS, OHIO.

The problem quoted as it stands in Hunter's Laboratory Manual is—"To determine where bacteria may be found." To do this a number of petri dishes were needed, containing sterile agar.

A petri dish is a small, flat glass dish with a cover which fits loosely. Sterile agar is more commonly known as gelatine. A thin layer of this was placed over the bottom of the petri dishes.

To solve this problem we exposed a number of these petri dishes containing nutrient for the same length of time in the following conditions:

- (a). To the air of our civic biology class room.
- (b). In the halls of the school while pupils were passing.
- (c). In the halls of the school while pupils were not passing.
- (d). At the level of Pearl and Gay streets, a supposedly dirty corner, for fifteen minutes.
- (f). In a downtown theater at the evening performance.
- (g). At a lumber company in the north end of Columbus.
- (h). To dirt from the hands of a pupil.
- (i). To contact with the interior of the mouth of one of the pupils.
- (j). To contact with the dust from a dustrag used in the class room.
- (k). To contact with a new one-dollar bill.
- (l). To contact with three hairs from a pupil's head. *

After two days we made a chart and noted the conditions of the various plate cultures on it.

Following is the chart:

	Number of colonies of bacteria			
	Jan. 13.	Jan. 14.	Jan. 18.	Jan. 20.
(a). To the air of our Civic Biology room.....	1	5	18	37
(b). In the hall of the school while pupils were passing 23	75	238	265	
(c). In the hall of the school while pupils are not passing.....	2	5	20	25
(d). At the level of Pearl and Gay streets.....	0	7	12	35
(e). At the level of Tulane and Indianola.....	0	5	5	6
(f). At a theater in the evening.....	32	59	65	127
(g). At a lumber company.....	3	7	24	34
(h). To dirt from the hands of a pupil.....	3	7	7	11
(i). To contact with the interior of a pupil's mouth.....	0	0	15	16
(j). To contact with the dust from a dustrag used in the class room.....	50	238	480	1,023