

2,000 to 2,400 revolutions per minute, and the spindle is always kept a snug fit—also there must be no end play. A mixture of lard oil and No. 10 emery is used for lapping, this being found best for both the roughing and finishing operations. The mouth or bell-mouthed portion of the die is lapped with emery cloth of the same grade—No. 10. The lapping of a drawing die is an operation that must be very carefully handled. Not only must the hole be of the correct size, but the radii of the bell-mouthed portion must be exact. The correct lapping of the die is more a matter of experience than anything else, and it is practically impossible to give any definite information on the subject. One point, however, that should never be ignored is the fact that the lap should always be presented in a line parallel to the axis of the die. If it is tilted over the least bit to one side or the other a hole will be produced that will not only be out of round, but that will not be straight; that is, if the die were placed on the arbor, it would be found to run untrue because the hole would not be exactly in the center of the blank on both sides.

After the dies are lapped to the correct size and shape, they are ready for use in the press and are then turned over to the drawing press department. Drawing dies for all redrawing operations up to the final operation are used until they have worn approximately 0.0017 inch large. When they have become worn to a size this much greater than the actual diameter of the cup required, they are taken out of the press and annealed.

The dies are then reamed out to the next size larger—that is for the previous redrawing operation than that for which they were originally made—and used over again. This is repeated until the dies have been used five times. Redrawing dies made from Firth-Sterling steel of the carbon content previously given are good for making 40,000 cups before they have become worn too large. The peculiar point about this steel is that it does not warp out of shape in hardening and also does not produce any scratches on the work. It is of extremely fine grain, hardens well and produces a shell free from scratches and other imperfections. The only thing that makes it unfit for use is when it becomes worn too large. Otherwise the condition of the hole in the die is as good at the completion of 40,000 cups as it was when first used.

MAKING REDRAWING PUNCHES.

Redrawing punches are also made from Firth-Sterling steel, but the carbon content for the punch is considerably lower than that used for the die, and never should exceed over 0.60 per cent. There are a few points that require careful consideration in making drawing punches. In the first place, the stock should be centered as true as it is possible to get it. There is a good reason why this operation should be carefully done. If the piece of stock from which the punch is to be made has not been centered true, the finished drawing punch when hardening will be bent out of shape. The reason for this is that when a bar that has been incorrectly centered,

so that it runs eccentric, is turned, more stock is removed from one side than the other, and the turning, instead of being parallel with the grain, cuts across it; hence the ability of the steel to resist deflection in hardening is not as great as it would be, had the support not been removed from one side. The explanation given for this is that in rolling bar stock the fiber or grain of the metal is drawn out in practically a straight line and when this condition does not exist in the finished article distortion takes place, because, in cooling, the fibers of the stock revert to their original positions parallel with the axis of the bar.

Another point that is of considerable importance is that never less than 1/32 inch of material should be removed from the bar if the finished piece made from it is to be hardened. There is a certain decarbonizing portion surrounding a bar of stock that prevents the steel from hardening properly, and this decarbonizing portion should always be removed from those parts of the punch that must be hardened; if not, soft spots will be experienced.

The drawing punch should be heated in a muffle furnace very slowly until it has obtained the correct temperature, and while being heated it should be constantly rotated to prevent warping. The temperature to which drawing punches are heated varies from 1,400 to 1,425 deg. Fahr. They are quenched in a bath consisting of 15 parts water and 1 part common potash, and are dipped in a vertical position as illustrated in Fig. 14.

On the Relation of Mathematics to Engineering*

Anticipating the Needs of the Engineer of To-morrow

By Prof. Arthur Ranum

How can we reconcile the fact that many a successful engineer uses very little mathematics in his work, with the further well-known fact that the profession of engineering rests to a large extent on a mathematical foundation? This question has many phases, one of which we can answer by pointing out that there is a vast difference between developing the mathematical theory that applies to an engineering problem and merely making use of the theory after it has been developed and put in tabular form by someone else. The latter process does not require very high mathematical attainments, but is sufficient for many practical purposes. In order to gain more light however, on this and other similar questions, let us try, if possible, to determine precisely what contributions mathematics has made to engineering; by looking back into the past, perhaps we shall discover some general law that will enable us to peer a little into the future.

Engineering has been defined as the art of directing the great sources of power in nature for the use and convenience of man. Now power implies energy, force, motion. Modern science has shown that all the phenomena of nature, including heat, light and electricity, are manifestations of energy, modes of motion. In order to direct the forces of nature, we must know how they act, we must understand the laws underlying the different kinds of motion, molecular as well as molar. Mechanics is then the fundamental science on which engineering depends. The other branches of physics reduce, in the last analysis, to mechanics. Now in the case of a moving body, molecule, or electron, the first thing we want to know is its velocity and the next is its acceleration. Both of these are rates of change or derivatives. Hence it is the most natural thing in the world to introduce the calculus into mechanics. The mathematical notion of a derivative is not something imposed upon mechanics from without; it belongs to the very essence of the science. Every waterfall, every bird on the wing, every ray of sunlight, every flash of lightning, when interpreted in mechanical terms, speaks the language of the calculus.

We must guard, however, against the error of supposing that mathematics can furnish us with any of the facts on which the laws governing physical phenomena are based. These facts can only be found by observation and experiment. But when once a precise physical law has been discovered, the function of mathematics is first to provide it with a language adequate to express all its complex and delicate content, and second, to interpret its hidden meaning and derive the consequences that flow from it, when the other known physical laws are taken into account. This means that the mathematician builds on the given foundation of experimental laws a logical structure, which often contains new theorems of far greater physical significance than the original ones from which they are derived. It is in this sense that mathematics has been described as the master-key that unlocks the secrets of nature.

Sometimes, moreover, a mathematical development of this kind leads in the most unexpected fashion to important practical applications. The delicate and exhaustive experiments and far-reaching generalizations of the physicist, the profound and searching analysis and rigorous thinking of the mathematician, the ingenious and practical resourcefulness of the inventor, are all three necessary factors in the progress of engineering. The influence of the last of these, the inventor, although more direct and easily understood than the others, is not therefore necessarily the most important. On the contrary, his work is often a mere corollary of the scientific research which has prepared the way for him. The history of science furnishes countless illustrations of this. The development of electricity in general, and the discovery of wireless telegraphy in particular, are striking examples, which I cannot describe better than by quoting from Whitehead's recent "Introduction to Mathematics."

"The momentous laws of electric induction were discovered by Michael Faraday in 1831-32. Faraday was asked: 'What is the use of this discovery?' He answered, 'What is the use of a child—it grows to be a man.' Faraday's child has grown to be a man and is now the basis of all the modern applications of electricity. . . . His ideas were extended and put into a directly mathematical form by Clerk Maxwell in 1873. As a result of his mathematical investigations, Maxwell recognized that under certain conditions electric vibrations ought to be propagated. He at once suggested that the vibrations which form light are electrical. This suggestion has since been verified, so that now the whole theory of light is nothing but a branch of the great science of electricity. Also Herz, a German, in 1888, following on Maxwell's ideas, succeeded in producing electric vibrations by direct electrical methods. His experiments are the basis of our wireless telegraphy."

We shall appreciate the important place which mathematics occupies in practical affairs, if we try to imagine what would happen if all the contributions which mathematics has made and which nothing else could make to the progress of engineering were suddenly withdrawn. The result would obviously be terrific; it would mean nothing less than the total collapse of all industry and commerce, and indeed the complete annihilation of all the external evidences of our material civilization.

"But why," asks the practical man, "do mathematicians and physicists concern themselves so much about certain fields of research which can never, in all likelihood, lead to practical results?" Two good reasons can be given. First of all, truth is one and indivisible; every part of the structure of truth has some bearing on every other part. Sometimes the most theoretical investigation is nearest to the most practical application. Nothing could at first have seemed further removed from the concerns of our daily life than the study of the radiant energy connected with Crooke's tubes, on the one hand, or the use of the so-called imaginary numbers, on the other—and yet look at the practical value of X-rays and of alternating currents, the latter depending essentially on these same imaginary numbers.

Moreover, certain branches of mathematics are no less important because their influence is indirect. In order to gain a thorough understanding of alternating currents we must study the properties of Fourier's series; and to understand Fourier's series we must study the theory of functions and of differential equations. These latter again depend on various other disciplines like the theory of equations and the theory of groups. We can never know too much about the space in which we live; hence the practical value of the modern developments of geometry, projective and metrical, analytic and synthetic, algebraic and differential, euclidean and non-euclidean, and even n -dimensional, because from one important point of view our ordinary space is four-dimensional.

But a more fundamental reason why truth should be pursued for its own sake is the simple fact that man is endowed with a divine curiosity, a desire to penetrate the secrets of nature. He wants to understand, among other things, the outer physical universe in which he is immersed and also the inner universe of logical thought revealed by mathematics. Are not the wonders of non-euclidean geometry and non-newtonian mechanics sufficiently valuable in themselves, without any reference to their practical bearing? The recent discovery that the atom, formerly thought to be indivisible, is really a complete world in itself, a sort of solar system so to speak, is surely of immense interest to every thinking person merely as affording a glimpse into one of the hidden recesses of truth.

Although the sciences of mathematics and physics are very closely related, they have not always kept perfect step with one another in their development. This is due partly to insuperable difficulties on the one side or the other and partly to an unfortunate lack of co-operation between mathematicians and physicists. For instance, the physicist has sometimes come to the mathematician for the solution of a problem, but has been compelled to wait a long time for the proper theory to be developed. A classic instance is the problem of three bodies in astronomy, which was discussed in detail in the last issue of the SCIENTIFIC AMERICAN SUPPLEMENT.

More often, however, the mathematician develops a body of doctrine, and only after a long interval does it turn out to have important applications to physics or engineering. The pure mathematics of one epoch becomes the applied mathematics of a later epoch. Maxwell's theory of electricity, before referred to, is a case in point; the mathematics he used depends essentially on principles which had been known for a long time. The discovery of the calculus was due to the attempt to find the lengths and areas of curves; later its immense significance in the science of mechanics was realized. The conic sections were investigated by the Greeks over two thousand years ago; and even to-day we are constantly finding fresh uses for them. Logarithms were discovered three hundred years ago, and the logarithmic function (or the compound interest law) now proves to be one of the commonest and most important laws governing the phenomena of nature. The

* Reproduced from the Sibley Journal of Engineering.

elliptic functions were first invented as pure mathematics, and then applied to the motion of the pendulum and other physical problems. The theory of groups has found a most unexpected application to the problem of determining the different types of crystal structure. Very recently the principle of relativity has appeared on the scene and threatens to revolutionize the science of mechanics; but its natural geometric interpretation turns out to be a non-euclidean geometry that has been known for thirty years or more.

The history of Fourier's series is a fine illustration of the mutual dependence of mathematics and physics. Originally due to the solution of a problem in the flow of heat, it soon acquired a position of capital importance in pure mathematics as the general expression for a simply periodic function. But since periodicity is a well-nigh universal law of nature, Fourier's series soon returned to the physical camp, where it now serves as the appropriate vehicle for expressing a large number of different kinds of periodic motion, including sound waves and alternating currents.

Can we make any prediction as to the future prospects of engineering? If progress continues along the lines followed in the past, one thing, at least, we can foresee with great confidence—the pure and applied mathematics of to-day, with its enormous and ever-growing body of splendid achievements, will surely lead, sooner or later, to a variety of practical applications and new inventions that will startle the world. The material and utilitarian progress of to-morrow will depend largely on the scientific progress of to-day. Moreover, the increasing demand for accuracy and efficiency in engineering can be met only by broadening and strengthening its mathematical foundations. Many an engineering student of to-day will live to see the time when those engineers who are leaders in their profession, who are capable of meeting novel conditions where originality of thought and action are required, will be men who are better equipped on the scientific side than we think necessary to-day; they will be men who are thoroughly trained in the use of many of the higher branches of what we now call pure mathematics.

Method for the Graphical Construction of a Direct Reading Scale for Wheatstone Bridge

By J. Carl Fisher

IN SOME of my work I found occasion to graduate a direct reading scale such as is used on the Kohlrausch-Wheatstone bridge, as sold by most manufacturers. A graphical method seemed desirable, and I finally found a simple one which serves the purpose admirably.

Referring to the upper diagram, AB is a straight wire which is divided into two variable segments P and Q by the slider S . This in turn is connected by a wire through the galvanometer G to the midpoint between the unknown and known resistances, x and R respectively. The current from the battery divides at A , part flowing through PQ and part through xR to B . The

fall of potential, or pressure, is the same in the two branches, PQ and xR . Hence, if S is at such a position that the fall of potential is the same through P as through x and through Q as R , M and S are at the same potential and there will be no current forced through the galvanometer. We then say a balance has been obtained and the proportion $P:Q = x:R$ holds true. If we call the length AB , l , then $Q = l - P$; also let the ratio $x:R = m$ a constant. Then we have $m = P/(l - P)$, and $P = ml/(m + 1)$. If we take successive arbitrary values of m , we may find P in terms of l and make out a complete table from which a scale could be graduated by laying off successive values of m with dividers. This much I believe is familiar and I have given it merely to make clear what follows.

Referring now to the large diagram, assume a scale unit which is one tenth of the length to be graduated, lay off an indefinite line EA and graduate it in equal parts, starting from D , distant one unit from E , as zero. At division 9 erect a perpendicular AB which is the length of the scale to be graduated. Through C on this line, and distant one unit from B and D , draw a straight line which thus makes an angle of forty-five degrees with EA . Erect perpendiculars from the division points of DA to this diagonal, and through their points of intersection draw lines from E intersecting AB . The division points thus obtained on AB should be marked with the same numbers as the corresponding points on DA . So much for the construction.

Suppose the slider, at the point of balance, is at such a position as t , which I have taken at the point 2 for convenience. The corresponding point on DA is r , and on the diagonal DC is s . The line Et makes the angle θ with EA . Now $At/EA = rs/Er = \tan \theta = a$ constant for this particular position of the slider. But $At = P$; $EA = AB = l$; $rs = rD = m$; $Er = m + 1$. Substituting, the proportion reads $P/l = m/(m + 1)$ and $P = ml/(m + 1)$, which is the formula previously deduced. Here we have the geometrical or analytical proof of the construction.

A practical difficulty arises in the graduation of the portions of AB lying between A and 1 and between C and B . It will be found advantageous to lay out the whole diagram on a large table or floor and by using a fine silk thread attached at E , and an assistant, to graduate CB . From A to 1 we will have to be satisfied with the regular method, or supplement it with a calculated table laid off with dividers. As the most accurate work with a bridge is done between a point a little to the left of 1, and C , the graphical construction serves very well.

I do not know whether this process is new or not, but it is original so far as I am concerned, so I publish it in order that it may be of use to someone else.

To Clean Sinks and Bathtubs

PERMANGANATE of potash salts thrown in sinks and bath tubs will deodorize all stagnant water and destroy all vermin that may have collected in the piping.

It is harmless, and any amount will work until it is all used up. It does not color the porcelain fixtures, but should not be splashed on the walls.

The World's Machines

From information published by the *Annuaire de la Statistique*, it appears that Germany exports the most machines and Russia imports the most. The following figures give the relative money value of machines imported and exported for various countries (1910):

	Exportations.	Importations.
Germany	575	80
England	526	77
United States	372	54
France	63	195
Belgium	62	71
Austria-Hungary	32	113
Italy	6	90
Russia	3	307

It is also to be remarked that the exportation figure for Germany is constantly increasing. In the following year, 1911, it reached 680.

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