to condense on the walls, since it is now cooled down to saturated steam and is in the same condition as the steam which we use in ordinary steam engines. But instead, the exhaust of the "high" is sent to the second set of coils, placed just after the first set, where it is again superheated, this time to about 400 degrees, the temperature of the steam itself being only 235 degrees when it leaves the high-pressure cylinder. Thus reheated, it is admitted to the low-pressure cylinder and expands against its piston right down to the vacuum of the condenser, arriving there in an exactly saturated condition, not having lost a drop by condensation. In the condenser, its work having been done, it is instantly condensed to water, producing the vacuum which is of such essential importance in the economy of any compound engine.

This, in a word, is the whole history of the use of superheated steam in a locomobile.

It must not be supposed that all these economies were obtained without a long struggle against the practical difficulties of using superheated steam. Since 1891 it has been a slow industrial advance with half a dozen large engine builders of the first caliber behind it; to say nothing of such able firms as Krupp, Bolinckx, and Tosi who were developing slow-speed ventil-gear engines for superheated steam at the same time. Gradually, through trial, failure and partial success, engines have been developed capable of ordinary everyday service in meeting the practical requirements of superheated steam. It is a subject on which most American engineers have but little practical knowledge. This steam at 570 deg. Fahr. is so hot as to carbonize any but special lubricating oils. It will char all soft packings of the piston and valve rods, and melt many of

the soft-metal packings ordinarily used. Any attempt to use it in an engine designed for plain saturated steam, as has often been tried in this country, is bound to result in failure. One of the largest makers in Europe, a firm that has already turned out over 22,000 locomobiles averaging two to three hundred horse-power each, has overcome the lubricating difficulty by designing so as to require none, precisely as in large marine steam engines. The valve is a specially designed piston-valve with cast-iron rings and a cast-iron bushing, which soon acquires the well-known diamond-hard, glassy surface of cast-iron wearing on cast-iron in the presence of steam. Another manufacturer whose output of locomobiles exceeds 24,000 running up to 1,000 horse-power in size, uses a special adaptation of the "ventil" or poppet-valve gear. This is simply a steam poppet valve lifted off its seat by a suitable cam and having therefore no sliding friction.

As to valve rod packing, the locomobile manufacturers have avoided trouble with it by the simple solution of having none at all. You can harden the surface of steel rods and then grind them into chilled steel bushings so as to produce a tight fit, provided that you turn shallow rings on the surface of the rod, making what is known as "labyrinthine packing" wherein the steam blocks itself as it were in the ring spaces and condenses before it can get out. In one make of locomobile the valve rod is on the exhaust steam side of the valve. The bushings are very long in proportion to the diameter of the rod, yet the friction is so little that very light and sensitive governors can be used on these engines. The piston rods are packed by a cast-iron labyrinthine cage which operates on somewhat the same principle; each exhaust stroke draws out from

the inside all the steam which forced its way into the rings of the labyrinth during the previous steam stroke, so that the steam never gets a chance to escape to the outside air. Expansion strains are provided for by making the frame open and free to extend without introducing internal stresses anywhere, and, in the piping, wrought iron with steel fittings have been adopted in place of brass and copper, as the last lose considerable strength at the temperature of superheated steam.

We illustrate here a few typical plants: Fig. 4 shows a 580-horse-power locomobile with double superheat and condenser.

Fig. 3 is a 200-horse-power compound locomobile with both high and low pressure cylinders cast in one piece with the steam dome, being jacketed by the live saturated steam of the boiler, so that radiation from the cylinder is returned direct into the steam. This is a favorite form of jacketing with one of the largest firms, and its engineers prefer it to jacketing with waste heat from the flue gases in the stack. The list below will give some idea of the distribution of these engines in the industries. It is the sales list of just one company. There are at least two others which can equal this, both in horse-power and number of engines.

Woodworking trades.....	1,885	Milling trades.....	1,253
Ceramic trades.....	1,400	Mining trades.....	837
Iron and metal works.....	1,429	Paper and printing	
Building trades.....	337	works.....	224
Electric lighting and		Quarries.....	167
power stations.....	1,615	Textile industry.....	337

Total9,484

Four-dimensional Space Its Application to Practical Problems

By E. L. Du Puy

IN ordinary geometry we study the straight line, which has one dimension only; the plane, which has length and breadth; and lastly, solid bodies, in which we have to consider length, breadth and height. Mathematicians, with their characteristic spirit of generalization, after having studied the systems enumerated above, have been led to conceive—in a purely theoretical way, of course, without giving any thought to any possible physical realization—bodies which could be completely described only by specifying four magnitudes, length, breadth, height and extension. This last dimension corresponds to nothing that our senses are capable of perceiving in combination with the other three dimensions; but in combination with any two of them it forms three-dimensional space, analogous to that in which we live.

It is possible to arrive at the conception of this four-dimensional space by purely physical considerations, as has been shown by the illustrious French mathematician, Henri Poincaré, in his remarkable book, "Science and Hypothesis." When we look at any solid body, its image is formed upon our retina, which, of course, extends in two dimensions; what we have here is a representation in perspective. If the object under consideration is allowed to move with respect to our field of vision, we see a series of perspective views which, with the assistance of various muscular sensations and our sense of touch, enable us by unconscious synthesis to form an idea of three-dimensional space, derived

Fig. 1.—One-dimensional line diagram for mixture of two components.

Fig. 2.—Melting point curve for a binary mixture represented in the line diagram, A B.

Fig. 3.—Gibbs' two-dimensional triangle diagram for mixture of three components.

Fig. 4.—Ternary diagram in perspective and projection.

Fig. 5.—Three different aspects of a tetrahedron diagram for a mixture of four components. Isothermal surfaces for the system: water, ethyl alcohol, NaCl, Na, SO.

DIAGRAMS FOR REPRESENTING MIXTURES AND THEIR PROPERTIES

from a series of two-dimensional views succeeding one another according to a definite law.

An analogous line of reasoning enables us to represent to our minds a body of four dimensions; in fact, the perspective view of such an object would be a three-dimensional solid. We can, therefore, form an exact a representation of the four-dimensional body as we please, and from this pass on to a conception of the object itself.

The space thus defined can be and has been made the subject of numerous applications, both mathematical and physical. We shall say nothing with regard to the former class, the examples of which are exceedingly numerous, and which, moreover, require more intricate mathematical treatment than can be rendered here. We shall restrict ourselves to a number of examples showing the application of space of more than three dimensions to the study of chemical systems. Here this application has been the outcome of the use of the method of Cartesian co-ordinates. Let us consider all possible mixtures of any two substances, such as, for example, lead and tin. On any straight line A B divided into one hundred equal parts we shall always be able to locate a series of points M, such that, the length A M being proportional to the percentage of lead in the mixture, the segment M B will represent upon the scale of the drawing the percentage of tin. Our system is, therefore, represented in this case by a figure of one dimension.

If, now, we are to represent in our diagram a property of a mixture, for instance, its solidifying temperature, as a function of the composition, all that is

necessary is to draw at every point, such as M , of the line AB , a perpendicular Mm proportional to the corresponding temperature. The join of the extremities of the perpendiculars will furnish a curve, such as CED , by the aid of which may be deduced from a limited number of experiments, and recorded upon the two-dimensional diagram, the melting points of all possible mixtures of the tin and lead.

Let us now consider a mixture of three bodies: lead, tin and bismuth, for example. In order to represent this system we shall make use of Gibbs' two-dimensional triangle diagram. Let us represent by each of the three apices of an equilateral triangle one of the three metals entering into the alloy. The sides of the triangle then represent in the manner just explained binary mixtures. Let M be any point in the interior of the triangle. Consider the three distances Mp , Mq , Mr . It is known to mathematicians that $Mp + Mq + Mr = \text{constant}$. If we give to this constant the value of 100, it will be seen that the point M will be the representation of an alloy containing

Mp per cent of the metal A ,
 Mq per cent of the metal B ,
 Mr per cent of the metal C .

If now, we wish to represent a property of the mixture, such as, for instance, its solidifying point, we

must draw at each point M a perpendicular Mm , whose length is proportional to the temperature in question. The totality of the points m then form a surface. Our representation is a three-dimensional figure. We can, however, in various ways, give expression to this by means of a surface of two dimensions; for instance, by means of a drawing in perspective or by means of a system of contour lines of the curved surface, such as are employed in indicating upon a map the relief of the earth's surface.

Let us now consider a system containing four constituents, as, for example, a special steel, containing in addition to iron and carbon, such a pair of elements as silicon-manganese, nickel-vanadium or chrome-vanadium. (It should be remarked that no complete investigation has as yet been made of such systems, owing to the incompleteness of our knowledge regarding the ternary systems of which they are composed.) Our former representation will now no longer suffice for our purpose, and we shall be forced to make use of an equilateral tetrahedron, any interior point of which represents a definite percentage of the mixture. The four corners of the solid figure represent the pure constituents. The edges represent binary mixtures, and the faces ternary mixtures. Let us now attempt to represent the solidifying temperature as before. We

find ourselves in a peculiar predicament, for the problem before us is to draw at the point M a perpendicular to the tetrahedron, in such direction that this line shall meet none of its faces, or, in other words, in such manner that it shall issue from within the solid without passing through any of its faces. There is only one way out of the difficulty, namely, to construct our diagram in space of four dimensions; but how are we to represent this to our mind? We must construct a series of tetrahedra, representing the mixture; on each we must mark the points M corresponding to a composition, the solidifying point of which is some selected temperature. These points, when joined together, form a series of surfaces, each of which separates at a given temperature the liquid zone from the solid zone.

It must not be supposed, by the way, that the number of dimensions taken in view by mathematicians is limited to four; it is in fact unlimited, for, continuing successively the line of argument indicated above, with each fresh constituent a new dimension is introduced. Some mathematicians have even gone so far as to speak of fractional dimensions.

Enough has been said to show that the conception of hyperspace is not an absurdity, but that, quite on the contrary, it is capable of rendering the greatest practical service to science.

Correspondence

[The editors are not responsible for statements made in the correspondence column. Anonymous communications cannot be considered, but the names of correspondents will be withheld when so desired.]

Life-nets at Niagara

To the Editor of the SCIENTIFIC AMERICAN:

Has not Niagara taken toll enough of human life? It seems astonishing that the best mechanical brains of the land have not before this attacked the problem of adequate life-saving devices for the river above and the rapids below the cataract.

In the first place, there should be created by joint action of Congress and Canadian Parliament an international Niagara Life-saving Commission. A patrol of picked men from the provincial and New York State police forces, respectively, should be formed. These should do much more than is now being done to prevent the reckless, the intoxicated, the ignorant and the unwary from getting into dangerous situations. Had such a force kept the people from the ice-bridge, we would have been spared the heart-rending tragedy of Sunday, February 4th. But it is not to be supposed that human nature will cease to take risks, and therefore from time to time the multitude will be telephoned up to throng the banks and watch the terrible spectacle again. When these times come there should be something more than loose rope-ends dangling from the bridges as a basis of hope for those who are going down to death.

Simple and perfectly practicable is a long life-net on each bridge, extending the length of the bridge over the water, each net to be 6 or 8 feet wide, with meshes large enough for clinging hands and feet, and suspended by tested ropes from a steel rod running the length of the bridge and connected with a powerful motor. The nets should hang, edge down, at the very surface of the water. Then, when a helpless boat comes drifting toward the fall, the occupants, as the boat strikes it, can easily seize the net, climb upon it, the bridge-motor will be started, the steel shaft will wind up the ropes and the net with its human burden be raised in safety to the bridge floor.

Through the influence of the SCIENTIFIC AMERICAN, these suggestions or better ones ought at once to open the way to action, else the death-roll goes right on.

Malden, Mass.

HENRY J. KILBOURN.

"Suction" as a Cause of Collision

To the Editor of the SCIENTIFIC AMERICAN:

The accident to the British cruiser "Hawke," pictured in a recent number of the SCIENTIFIC AMERICAN, and the inquiry into the cause of the accident, are most interesting. On the shallow waters of the Mississippi River the effect of suction is well known to every navigator. We have a canal here with about five feet of water and some large boats. These boats are obliged to go at a snail's pace through the canal, because if forced at all they cannot be steered. I have often watched such a boat from her deck, and seen the effect on her of the wave that follows and precedes the boat.

As soon as she is forced, unless exactly in the center of the deepest water, a wave piles up on one side of the bow or the other. This wave boxes her off her course; so that, unless stopped and the wheel set to backing, she turns at right angles to her course. I was on a boat one night going through the canal, and

the boat was loaded down deep for such a boat. We went along at a slow crawl; but every now and then the boat would take a sheer from one side or the other. The pilot would stop the engine and set her to backing, and after getting her straight would start on again. This happened every quarter of a mile, and was exhausting to the pilot. I remember well his exasperation and his remarks. "You are a hog, 'Mary,'" he would say. "You are a hog." It seemed to relieve him to express his feelings that way, and yet that boat in deeper water steered as well as any.

Once I witnessed the very thing that happened to the "Hawke." It was on the famous river trip that President Roosevelt made down the river to Memphis. Leaving Cairo, there was a mob of boats none too well disciplined, and among them one of the largest tow-boats of the Ohio River. This boat was a bully among the smaller boats, and arrogated to herself and owners the position of honor next the president's boat, though she had been assigned a humbler place. By dint of weight, size, and strength, she took what she wanted, and there was no means to make her obey the laws of decency. As the fleet were leaving Cairo she started off to capture the best place, and was raced by a swift little boat out of the Illinois River. The little boat gained on the big one, and would have passed her had not the big one pinched her toward the shore. Suddenly the thing happened that occurred to the "Hawke." The little boat, caught with the bank of the river on one side and pulled by the suction of the larger boat, suddenly was sucked up against the larger boat's side and stuck there, and, as long as they kept going, no power could separate them. The little boat was captured like a satellite by a planet, and as they went along together she stuck to the big boat like a barnacle, and having about as much effect on her as a barnacle would.

It was only by stopping the engines of the little boat that they were able to get away, and then they nearly got under the wheel of the bigger boat. It is well known on this river that two boats, racing, will lock together and stay locked if allowed to come too close.

In the "Hawke" affair it seems evident that the wave piled up on the shoal side of the "Hawke's" bow and the bigger boat captured her, head on this time, to the damage of both the "Hawke" and "Olympic." I guess it was a case of racing and the big boat bullying the little one and crowding her into shoal water. There are gentlemen and there are bullies both afloat and ashore. The latter class is not unknown out here.

Keokuk, Iowa.

M. MEIGS.

An Explanation of the Olympic-Hawke Collision

To the Editor of the SCIENTIFIC AMERICAN:

The very interesting article in your issue of February 24th, with reference to the collision between the "Olympic" and the "Hawke," emphasizing the value of a knowledge among maritime officers of the existence of the force designated as "suction," inspires the following explanation. It would appear that the term "suction" is a misnomer. Every boy who has sailed boats on a pond knows of this force, but suction would be difficult of demonstration in this connection. Science has long recognized the fact that our earth is enveloped in a magnetic, or electric, field, as is everything on its surface; that the magnetic currents have definite direction; that all force is in a sense electrical; that all cells have polarity; that unlike poles attract, while like poles repel. Two vessels in proximity are evi-

dently in the same magnetic field and have similar polarity. Taking the established fact that as one vessel approaches to pass another, the bow of the forward ship turns from the "overtaking" vessel, and, as the latter passes, a reverse movement occurs, we have first the attraction, let us say, between the positive bow of the "overtaking" vessel and the negative stern of the forward ship; as they come abreast, the effect is neutralized, they lie parallel, and the drift brings them closer together; then, as one forges ahead, again occurs the attraction between the opposite poles of the stern of the one and the bow of the other, drawing the bow toward the passing ship. This may be practically shown by means of two magnetic needles, which for the purpose of demonstration may represent the respective vessels. As one approaches and passes the other we will have the following phenomena of magnetic attraction: The larger needle, or vessel, will exert the stronger force, and maintain more nearly its own equilibrium. With the needles, if one is somewhat larger than the other and moves steadily by it, though both will be deflected, the smaller will swing fully forty-five degrees, and in the case of two moving vessels a collision will naturally follow.

Roanoke, Va.

F. C. TICE.

Steering Aeroplanes

To the Editor of the SCIENTIFIC AMERICAN:

The article entitled "Difficulties in Steering Aeroplanes" in the February 10th number of your paper, written, as its author says, to draw out discussion, is not very clear as to what he means. Gyroscopic force has been suggested to keep the aeroplane in its course while here it is said to cause the machine to travel in a circle.

The writer also says the machine turns the opposite way to the motion of the propeller. The propeller turns on a horizontal axis while the machine in turning right or left turns on a perpendicular axis. Then which is the "opposite way?" If he means opposite the way the top of the propeller is going why opposite the top more than opposite the bottom?

Is it not just possible that in his case the propelling power is not located exactly in the center of resistance?

Niles, Mich.

W. G. BLISH.

A Turntable Airship Shed

To the Editor of the SCIENTIFIC AMERICAN:

As a constant subscriber to your paper for a number of years, I have been deeply interested in your accounts of the progress of aerial navigation, and have followed its development as they were made from time to time. As the dirigible airship has been brought to greater perfection, and the size has increased greatly, the difficulty of getting them in and out of the shed in a cross wind has caused a lot of trouble, and a number of wrecks. Now it has occurred to me that a very simple way out of the difficulty would be to have the shed mounted as a turntable, so that it could be turned to face the wind, and the airship could then be taken in or out head to the wind at all times. It might be manually operated, or run by a small motor. As this seems such a simple and easy way out of the difficulty, I send the suggestion with the hope that at least one step more may be made in the art.

A. C. LAWRENCE.

[The idea suggested by our correspondent has already been carried out by the Siemens-Schickert Works. The "Krell I," built by the firm, is housed in a shed that swings on a turntable.—EDITOR.]