that it is not necessary to expend any power in keeping them suspended in the air at high velocities, bring the study of the problem of aviation within more reasonable limits.

Then there is the saying of Jules Verne of twenty years ago, that it is not necessary for imitation of bird methods to be servile, as for example locomotives are not copied from hares, nor ships from fish. To the first we have put wheels which are not legs, and to the second screws which are not wings.

This idea of the propeller suggested the avoidance of the difficulties of wing construction, and the sailing of the albatross suggested the aeroplane The combination of the two would, it struck many inventors, answer the two-fold purpose of the bird's wing. Moreover, the fact was well understood that the air is highly resistent—a parachute of a yard in diameter in practice not only impeded descent but made it isochronous On the other hand there was the kite, the plaything of generations · men had even crossed rivers, towed over by kites of which they held the strings. Science studied the kite. The result is given by the authority we have already quoted thus —

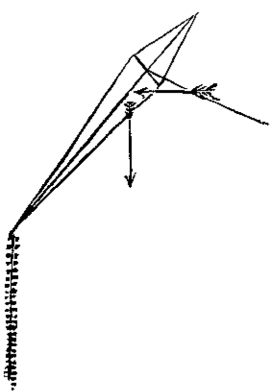

FIG 1.

"In figure I a kite is shown. The wind blowing against it in the direction of the horizontal arrow is deflected at the same angle. If then the kite be declined at an angle of 45°, the wind is deflected vertically downwards and the kite forced upwards with equal force. Referring to the diagram (Fig 2) let E F equal the weight of the kite in pounds, B D the force of the wind on the kite in pounds, A B or B F upward force caused by the rebound of the air; B C direction of string Completing the parallelogram we find an unbalanced power tending to raise the kite; the kite will therefore rise till the angle D B C, becoming more acute, the quantity B G increases until it and E F

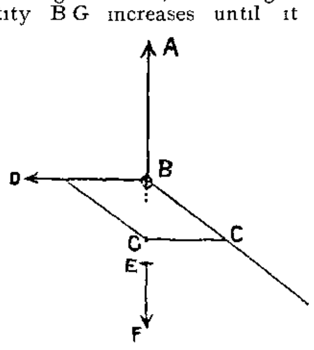

FIG 2

(dead weight of kite) become unitedly equal to B F (or A B), when the kite becomes stationary If, however, the wind lessens, the quantity B A diminishes, and the kite falls till the lessening quantity B G and weight of the kite E F again balance the upward force of the wind A B or B F. We see then as at an angle of 45 the wind is deflected vertically, and therefore gives the most lifting power, the tail ought to be weighted to such a degree as to cause the kite to stand at 45—that is, heavily in a high, and lightly in a gentle breeze Also that the nearer the thing approaches the horizontal the greater is the lifting power of the kite.

"Every one has doubtless played 'ducks and drakes' (*alias* throwing flat stones nearly horizontally over the surface of water) and has counted the number of leaps the stones have made before sinking into the water. All skaters, too, are familiar with the fact that a man can skate with impunity over ice that a boy could not stand on without immediately breaking through In each case velocity is a very important item; the skaters and the stones alike have not time to sink. A kite or plane traversing a stratum of air rapidly is supported in a similar way, not having time to displace each portion of the area traversed before entering a fresh portion

"Suppose a plane (A) slightly inclined moving rapidly in the direction of arrow B (Fig 3), the

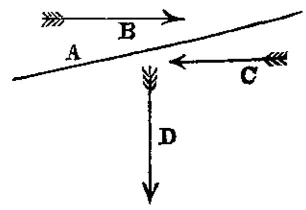

FIG. 3.

wind (arrow C), meeting the under surface of the inclined plane, is diverted downwards (arrow D), displacing the air below But air cannot be suddenly displaced without causing a great resistance, therefore if the plane goes fast enough the air forms an approach to a solid surface, like the water in the case of 'ducks and drakes'

"Now a solid projected through the air should present an edge or point to the air it cleaves, but if the planes of which it is composed have an uniform angle with the perpendicular, it makes little matter how these planes are placed. Thus A, B, C and D (Fig. 4) would have approximately the

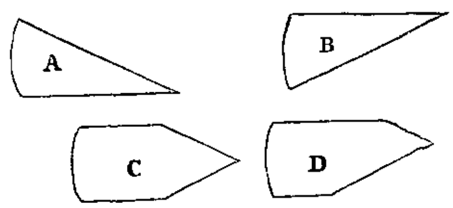

FIG. 4.

same resistance in cleaving the air point first. But A has a tendency to descend, B to ascend. If therefore we make a combination of these (C) it will be neutral, but it has, independently of its shape, a tendency to descend by force of gravity Let us therefore give a sufficiently great preponderancy to the lower slanting plane to neutralise the gravity, the result being D Now D thus weighed would require almost exactly the force to counteract the resistence of the given speed that A would destitute of weight We thus see that provided that we can alter the shape of the object at pleasure, at a high velocity, the amount of weight within certain limits causes little or no difference to the power required. How strikingly in this point the plane or kite differs as a means of keeping a weight suspended from the voluminous balloon."

There remains to consider the difficulty of making a machine rise as the bird rises for his flight. Take the albatross, which has to go some distance along the surface of the water before it gets up in the air How is a machine to be made to follow this example? The question was answered for the thinking by the analogy of the hydroplane They remembered that long years ago the Canadians constructed boats which did wonderful things on their big lakes; very strange craft of their invention beating everything that floated without being propelled by other than wind power That craft was called a "skate" It was a boat whose bottom was an inclined plane reduced to about one-third of normal width When sailing the skate showed a tendency to rise near to the surface of the water, and in strong winds with all sail set she actually did so skimming the water with a minimum of friction which enabled her to leave everything floating miles astern But the skate was, as may well be imagined a very dangerous craft, peculiarly liable to go over The advent of steam did not help matters, because while it made the craft safer by reason of the absence of sails, it dragged its propeller and therefore lost the superior speed For these reasons the "skate" went out of favour But its principle remains to give hints to the aviators Several of the competitors for pride of place in the invention they are seeking with such ardour have solved the problem of making their machines rise up from earth by provoking the resistance of the air.

The wing difficulty brings another in its train The question of that is raised by the question of the necessary length of the wing An albatross weighing only 24 lbs. has wings about 12 feet from tip to tip Therefore a man weighing 144 lbs ought by analogy to have wings each 36 feet long or 72 feet in all as shown in the diagram; and a flying-machine weighing 12 tons to take an extreme case by way of extreme illustration would require an extent of wings of 2½ miles from tip to tip The difficulty has been faced and in one case met by a proposal to supply machines with a row of wings on each side horizontally placed one behind the other, copying nature in fact after the example of many insects. In support there is also the analogy of the long flights of the migratory birds which arrange their flights so that the birds fly in single file In this case the air compressed by the first wing rebounding upwards forms a firmer cushion for the succeeding one to act upon, until there is set up an advancing wave and an induced current The proposers of this expedient, however, admit that some sort of parachute arrangement would be required, capable of expansion, at need "to break the fall" The difficulty is lessened by the further consideration mentioned above that but little power is required after sustaining the body in the air in comparison with the power wanted for propelling at speed. Still as some provision must be made for the sustaining power, after the fashion of the kite, and that provision must bear some relation to the weight to be sustained, the difficulty raised by the length of the wing which acts both as sustainer and parachute is considerable The power required for sustaining is estimated at something like the ninth part of a horse-power for 10 tons. Still the kite or parachute effect must be attended to. In practice nearly all the recent experimenters in aviation who have got their machines to rise off the ground have found that when they return to earth after their brief flights there is a great and sometimes disastrous tendency to bump.

Science has proposed to get over this difficulty by the use of horizontal screws This was the theory on which Jules Verne relied for the support of his renowned "Clipper of the Clouds." Pettigrew, the well-known authority, describes a model which developed later into a favourite toy. It was a plane provided with two vertical axes, each carrying a horizontal screw These screws being set revolving in opposite directions displace quantities of air above the plane, which cause a resistance of the rest of the air in the neighbourhood, forcing the plane upwards. The toy made on this principle was operated by clockwork, which at once set the screws revolving and set up the machine The gradual expenditure of power caused the upward movement to become slower until it ceased, after which the power sufficed to retard the descent till the machine returned without harm to the earth One or two inventors have experimented in this direction. Others have preferred the use of a tail arrangement for the vertical steering

In theory such a use of power (the double horizontal screws) would maintain equilibrium without fail and automatically. In practice the pressures from without would have to be taken into account. There are two centres in practice · the centre of gravity and the centre of pressure. The problem that so baffles aeronauts is the problem of reconciling these pressures, so to speak, and keeping them friendly In some thousands of gliding experiments some experimenters have managed to adjust the balance by shifting their own weight in one direction or another as need arose. There were many disasters, and besides, when working on a large practical scale, such adjustment is obviously impossible some mechanical expedient is needed, and it is imperative that it should have automatic action Some inventors of to-day make express admission to that effect

These were the devices for overcoming the supposed natural law of the proportionate wing surface, which discouraged invention so greatly by its reduction to the absurd. The true answer, however, was soon found It is that there is no such law. The natural fact, demonstrated by many measurements, is that the greater the creature supported in the air, the smaller the relative supporting force.

Mr. Langley, the American experimenter who built a flying-machine in 1896 which actually flew over half a mile, collected figures from which he obtained the following approximate results

Machine with 54 sq. ft. wing sustained 30 lbs. using 1½ h p

Pterodactyl, extinct flyer, with 25 sq. ft. wing sustained 30 lbs weight, using 0.05 h.p.

Condor with 10 sq ft wing sustained 17 lbs. weight, using 0 05 h p

Turkey Buzzard with 5 sq ft. wing sustained 5 lbs. weight using 0 15 h p.

Pigeon with 0 7 sq ft wing sustained 1 lb. weight, using 0 012 h p

Humming Bird with 0.03 sq. ft wing sustained, 0 02 lb weight, using 0 001 h p

On these figures he remarked "particular attention is to be paid to the fact that, regarding the ratios of supporting surface to weight supported, these ratios are not only not the same in all the birds, but themselves differ greatly, but systematically, with the absolute weight" If we enquire how much one horse-power would support for instance supposing the ratios of sustaining surface (i e wing area) to weight to be constant, we find that one horse-power will support in

The Machine 20 lbs. with 36 ft. of area or 1⅗ sq. ft. to the pound.