flector. Immediately after the first successful measures by Mr. Pease, both he and I made several designs of large interferometers with independent equatorial mountings, but their cost would have been too great to warrant their construction. It was also thought advisable to postpone further instrumental developments until they could be undertaken in the light of prolonged experience with the 20-foot interferometer.

The method has since proved so successful, and its wider application so desirable, that the mechanical problem has recently been taken up anew. Optically the 20-foot instrument leaves nothing to be desired. The new instrument is therefore simply a larger Michelson stellar interferometer adapted for the observation of fainter and smaller stars, embodying no new optical features, but carried by a mounting so simplified in design as to reduce the cost of construction to a minimum. My specifications for the mounting, which have been improved in certain respects and developed into working drawings by Mr. Pease and his associates in the Division of Instrument Design of the Mount Wilson Observatory, call for a light but very rigid skeleton girder about 54 feet long and 10 feet deep at its centre, where its cross-section is about $4\frac{1}{2}$ feet (Figs. 1 and 2). This is to be built of standard steel shapes, cut to length at the mill and riveted together on Mount Wilson. The girder will be bolted to a heavy plate carried by the upper extremity of the polar axis, which is a short steel forging turning in standard roller bearings, mounted on the upper face of a massive concrete pier. The polar axis passes through the centre of gravity of the girder, thus assuring its balance in all positions. A worm-gear sector of long radius, bolted to the girder, is driven by a worm connected with a driving-clock fixed near the north face of the pier. The range of motion in right ascension is $1\frac{1}{2}$ hours east and west, thus allowing ample time for the observation of a star when near its meridian passage.

The optical parts comprise a paraboloidal mirror of 36 inches aperture and about 15 feet focal length, mounted within the girder, as shown in the illustrations. The two outer plane mirrors, each 15 inches in diameter, mounted at 45° on carriages which slide along rails bolted to the upper face of the girder, receive light from the star and reflect it to two similar 45° plane mirrors, fixed in position above the 36-inch mirror, to which they send the two parallel beams. These are returned as converging beams toward the focus, but are intercepted by a (Newtonian) 45° plane mirror above the centre of the girder, which sends the light to the focal plane, in the direction of the north pole. The observer, seated on a platform carried by the girder, makes the necessary adjustments and determines the visibility of the interference fringes corresponding to various settings of the outer 45° mirrors, which are periodically moved apart by a single long screw driven by an electric motor. The distance between these mirrors, when the fringes disappear completely, gives the angular diameter of the star if the mean wave-length of its light is known.

To reach stars north or south of the equator, the two outer 45° mirrors are rotated simultaneously by synchronous motors about the axis joining their centres. In this way any star from the pole to 30° south declination can be observed when near the meridian.

Throughout the design precautions have been taken to reduce the amount of large and expensive machine work to a minimum. The girder need be only approximately straight, as the rails, carefully planed in 12-foot lengths (the limit of our planer bed), will be optically lined up by adjusting screws. The final compensation for length of path will be effected by a sliding wedge, of the type designed by Prof. Michelson for the 20-foot interferometer. Comparison fringes, adjustable for visibility, will be provided as an aid to the observer. The instrument will be covered when not in use by a sheet steel house with double walls, the upper part of which can be rolled away longitudinally by an electric motor.

This interferometer should permit the measurement of more than thirty stars brighter than the fourth magnitude, representing a wide range of spectral types. It is now under construction in the instrument and optical shops of the Mount Wilson Observatory.[2]

2 For a brief account of the 20-foot interferometer and its method of operation, see the chapter on "Giant Stars" in the writer's recent book "The New Heavens," reviewed in NATURE of July 11, p. 2. Full details are given by Messrs. Michelson, Pease, and Anderson in the *Astrophysical Journal*.

Motorless or Wind Flight.

By Dr. S. BRODETSKY.

RECENT achievements in motorless flight, variously designated as *gliding*, *soaring*, and *sailing*, have attracted considerable attention, and much discussion has arisen as to the practical and military value of this new development, as well as to its scientific significance. While many authorities anticipate nothing more than the emergence of a new "sport," and ascribe little importance to motorless flights, others of a more imaginative turn of mind foresee great possibilities in this type of aerial navigation. The motorless flying machine has even been proclaimed as heralding the doom of the engine-driven aeroplane!

It is certainly premature to attempt a forecast of the future of flight in a glider. The art of gliding is, of course, older than that of flight in an engine-driven machine: Lilienthal's experiments with gliders were made more than a generation ago, long before any aeroplane containing a motor rose into the air and executed a real flight. But Lilienthal, Pilcher, Chanute, Orville Wright, and others were not able to stay aloft in a glider more than a few minutes; whereas during the recent competitions in Germany, Martens remained in the air nearly three-quarters of an hour, and Hentzen stayed in the air two hours, and later three hours, performing evolutions of an intricate character. It is therefore clear that the art of gliding has entered upon a new phase, and the scientific problems involved merit careful discussion.

As already indicated, there is considerable diversity in the names given to the flights thus carried out without the aid of a motor. All the three names mentioned above are really unsuitable. The term gliding is reminiscent of descent in an aeroplane, while the real interest of recent events has been in the fact that pilots were able to stay in the air very long without the help of a motor, and in fact performed climbing feats. The term soaring is less unsuitable, but it suggests climbing as the essential thing, whereas, in reality, horizontal flight in a glider is just as different from aeroplane flight as climbing in a glider. Finally, sailing is quite inappropriate as a description of the flight in question. Perhaps the term *wind-flight* is a really suitable name for flying without a motor, as distinguished from *engine-flight* in an aeroplane.

The wind is indeed the main instrument of motorless flight. Whether birds and other natural flyers do or do not derive energy from the air in some mysterious manner of which we have, as yet, no knowledge is a question that does not arise in the present connexion. The successes achieved have been the outcome of careful study of design and of movements in the air. In construction the gliders used look like aeroplanes without engines, and the determining factors in the flights were the various types of winds that blew while the machines were in the air.

It is clear that in a quiescent atmosphere the net result of any motion through the air in a motorless machine must be a diminution in the total energy, *i.e.* in the sum of the kinetic and potential energies. It follows that in the absence of wind, real flight, namely, flight in which the machine maintains its level for some considerable time, or rises still higher above the ground, is not possible without a source of energy like an engine. It is the presence of wind that puts in the hands of the pilot a source of energy, which can be used to neutralise the loss of energy involved in motion through the atmospheric resisting medium.

Although it should be obvious that the wind must be upwards or unsteady in order to supply this energy, it is necessary to say a few words about the case of a steady horizontal wind, since it has been claimed that "once the airman has left the ground he gets his energy from *the wind*, which may be level and steady." This is not correct, as can be proved quite simply. If we write down the equations of motion of a glider through the air under the action of gravity, we get three types of terms:

(1) Accelerations in terms of the motion of the glider relative to the earth;

(2) Gravity components;

(3) Forces and couples due to air resistance, these being functions of the motion of the glider relative to the air.

It is useful to write the first terms, the accelerations, with reference to the motion of the glider relative to the air. When this is done for a steady wind, the resulting equations are exactly of the same form as if there were no wind at all, since the moving "air axes" move uniformly as seen from the "earth axes." This means that when there is a steady wind, we get the actual motion of the glider as seen from the earth, by adding the velocity of the wind to the motion of the glider in still air; in other words, to an observer travelling with the wind, the motion of the glider would not reveal any effects that can be attributed to the steady wind.

In a horizontal steady wind, therefore, real flight is no more possible without an engine than in absolutely windless air. Any argument that leads to a contrary conclusion must have a fallacy somewhere, if we are to have any confidence in the principles upon which all our mechanics are based. It is true that a steady horizontal wind can be used as an aid in gliding. Thus, by pointing his machine into the wind the pilot can get off the ground with less initial speed than in still air. Further, when the machine is already in the air the pilot can, by pointing it with the wind, increase the horizontal distance travelled before reaching the ground again. But a steady horizontal wind cannot make the machine stay at the same level in the air for any length of time, or climb. For these purposes the wind must be upwards or variable.

If the wind is steady, but has an upward component, it helps in the attainment of real flight, which we can call wind-flight. Thus, if a glider is so constructed that in still air it performs a straight line glide with speed U at gliding angle θ below the horizontal, then a steady wind of speed U, blowing at an angle θ above the horizontal, will keep the glider suspended in the air indefinitely, if it points into the wind. And, more generally, if the steady wind has speed U' at an angle θ' above the horizontal, where $U' \sin \theta' = U \sin \theta$, then the machine will fly horizontally with speed $U \cos \theta - U' \cos \theta'$ relative to the earth, if it is given this speed initially against the wind. If $U' \sin \theta'$ is greater than $U \sin \theta$, so that the vertical component of the wind is greater than the rate of vertical fall of the glider in still air, then the glider will climb with horizontal speed $U \cos \theta - U' \cos \theta'$ and upward vertical speed $U' \sin \theta' - U \sin \theta$.

These results are simple and obvious. Given a steady wind with sufficient upward vertical component, a glider can perform real flights and make evolutions similar to those of ordinary aeroplane flight.

It is not necessary, however, to postulate steady upward wind. If the wind is variable, and this is, of course, usually the case, energy can be derived from the wind, even if it is horizontal, or downwards. This can be seen by a little analysis based on the ordinary equations of motion of the glider. Thus, suppose that the wind is in a straight line, but of varying speed. If we write the accelerations in these equations in terms of the motion relative to the air, we readily find that the motion of the glider relative to the air is the same as if the air were at rest, and a force per unit mass were given to the glider, in a direction opposite to that of the wind and proportional to the acceleration of the wind. If the wind rises steadily from zero to U' in time t, the motion of the glider is found by taking the air to be at rest and assuming that on each unit mass there acts, in addition to the weight, a force U'/gt in a direction opposite to the wind.

If, then, the machine is pointed into the rising wind, and the wind varies quickly enough, flying becomes possible. If the wind is being retarded, similar propulsive effect is obtained by pointing the machine with the wind. It follows that in a fairly sudden gust, which can be taken to consist of a quickly increasing wind, followed by a quickly decreasing wind, the pilot can take advantage of both phases by pointing the machine into the rising wind, and with the falling wind. Quick manœuvring is, of course, essential, as well as an intimate acquaintance with the movements that are always taking place in the air.

With more complicated variations in the wind, more complex results are obtained. It is now clear, however, that the future of wind-flight is associated with three main lines of study:

(1) The motions that are continually taking place in the atmosphere need to be studied, not only the meteorological wind phenomena as ordinarily understood, but particularly the detailed air motions, the "internal structure of the wind."

(2) Motorless flight presents problems of design that are different from those of ordinary aeroplanes. This is because the glider is a much lighter machine than the aeroplane. Stability is essential, but easy control is a *sine qua non*, since so much depends upon taking as full advantage as possible of any temporary, and often unanticipated, motion in the air.

(3) The rigid dynamics of wind-flight is also an important factor in the progress of the art. Only in very exceptional circumstances can the motion of a glider be steady. Upward steady winds, or uniformly varying winds, are only of rare occurrence and brief duration, and in trying to perform real flight in an engineless machine the pilot must make use of any stray wind that comes to his aid. The motion in wind-flight must consequently be very variable. In this respect wind-flight must generally differ in essence from engine-flight. In the latter steady flight is the rule, in the former steady flight is bound to be a comparative rarity. The pilot must therefore learn from experience and from calculation to know what to expect from his machine under different conditions. The dynamics of wind-flight should be a fruitful subject of study both for the aviator and the mathematician.

The Influence of the late W. H. R. Rivers on the Development of Psychology in Great Britain.[1]

By CHARLES S. MYERS, C.B.E., M.A., M.D., Sc.D., F.R.S.

A MOURNFUL gloom has been cast over the proceedings of our newly born Section. Since its inauguration twelve months ago this Section, as, indeed, psychology in general, has suffered an irreparable loss through the sudden death, on June 4 last, of him who was to have presided here to-day. When, only a few weeks ago, it fell to me, as one of his first pupils, to occupy Rivers's place, I could think of little else than of him to whom I have owed so much in nearly thirty years of intimate friendship and invaluable advice; and I felt that it would be impossible for me then to prepare a presidential address to this Section on any other subject than on his life's work in psychology.

William Halse Rivers Rivers was born on March 12, 1864, at Luton, near Chatham, the eldest son of the Rev. H. F. Rivers, vicar of St. Faith's, Maidstone, and of Elizabeth, his wife, *née* Hunt. Many of his father's family had been officers in the Navy—a fact responsible, doubtless, for Rivers's love of sea voyages. The father of his paternal grandfather, Lieutenant W. T. Rivers, R.N., was that brave Lieutenant William Rivers, R.N., who, as a midshipman in the *Victory* at Trafalgar, was severely wounded in the mouth and had his left leg shot away at the very beginning of the action, in defence of Nelson or in trying to avenge the latter's mortal wound. So at least runs the family tradition; also according to which Nelson's last words to his surgeon were: "Take care of young Rivers." A maternal uncle of Rivers was Dr. James Hunt, who in 1863 founded and was the first President of the Anthropological Society, a precursor of the Royal Anthropological Institute, and from 1863 to 1866 at the meetings of this Association strove to obtain that recognition for anthropology as a distinct Subsection or Section which was successfully won for psychology by his nephew, who presided over us at the Bournemouth meeting in 1919, when we were merely a Subsection of Physiology.

Our "young Rivers" gave his first lecture at the age of twelve, at a debating society of his father's pupils. Its subject was "Monkeys." He was educated first at a preparatory school at Brighton, and from 1877 to 1880 at Tonbridge School. Thence he had hoped to proceed to Cambridge; but a severe attack of enteric fever compelled him to take a year's rest, and thus prevented him from competing for an entrance scholarship at that University. He matriculated instead in the University of London, and entered St. Bartholomew's Hospital in 1882, sharing the intention of one of his father's pupils of becoming an Army doctor. This idea, however, he soon relinquished; but, like his desire to go to Cambridge, it was to be realised later in life.[2]

When he took his degree of Bachelor of Medicine in 1886 he was accounted the youngest Bachelor ever known at his hospital. Two years later he graduated as Doctor of Medicine, and he spent these two and the two following years in resident appointments at Chichester (1888) and at St. Bartholomew's (1889) hospitals, in a brief period of private medical practice (1890), and in travelling as ship's surgeon to America and Japan (1887), the first of numerous subsequent voyages.

In 1892 he spent the spring and early summer at Jena, attending the lectures of Eucken, Ziehen, Binswanger, and others. In a diary kept by him during this visit to Germany the following sentence occurs: "I have during the last few weeks come to the conclusion that I should go in for insanity when I return to England and work as much as possible at psychology." Accordingly, in the same year he became clinical assistant at the Bethlem Royal Hospital, and in 1893 he assisted G. H. Savage in his lectures on mental

[1] From the presidential address delivered to Section J (Psychology) of the British Association at Hull on Sept. 11.

[2] For many of the above details of Rivers's early life and antecedents I am indebted to his sister, Miss K. E. Rivers.