AERIAL FLIGHT.[1]

BEGINNING with balloons, as having the priority in point of time, it may be remarked that the whole subject is included in the last 130 years dating from the experiment of the Montgolfiers, who made their first ascent in 1788, but were at work for some years before this, and that other designs quickly followed containing in principle most of the appliances which are in use to-day. The ballonet, for instance, was proposed and tried by Charles and Robert. We find also designs for dirigible balloons of much the same shapes as are now familiar to us.

All attempts at propelling these vessels naturally failed for want of adequate power, and in some cases the proposed form of propulsion was impracticable, but in others a screw of nearly the same proportions as that now in use was actually tried. It was soon found, however, that the speed which could be developed by man-power or by any engine that the balloon could lift only amounted to a few miles an hour, less, that is, than the speed of a very light breeze. Thus, so far as directing the course of a vessel was concerned, the mechanism was almost useless, and few further attempts at mechanical propulsion were made until the advent of the internal-combustion engine.

Independently of outward form, balloons may be divided into two classes, according as the lifting gas carried is (*a*) constant in mass, or (*b*) constant in volume, and these again may be subdivided according to the relation of the pressure or density of the enclosed gas to that of the surrounding air.

All the conditions, however, may be conveniently represented by supposing that the gas is contained in a massless vertical cylinder closed at the top by a fixed cover and below by a movable piston. The piston may be supposed to be free or clamped, and to be acted on by the gaseous pressures only or by any other additional force.

I do not propose here to go into the questions of the relative merits of the rigid and non-rigid forms, questions which turn on structural details rather than on general principles, but something may be said on the nature of the envelope used for retaining the hydrogen which is now usually employed for lifting purposes.

The best information on the subject is due to work recently carried out at the National Physical Laboratory at the request of the Advisory Committee for Aëronautics, and will be found in detail in their published reports.

It appears that among the fabrics in use there are enormous differences in their retentive power (that is, in the rate of the diffusion of hydrogen through them irrespective of actual leaks), differences of nearly two hundredfold appearing between the worst and best specimens.

Indiarubber coatings are the least satisfactory, allowing an escape in some cases of more than 0·7 cubic foot for every square foot of material in twenty-four hours when new, and deteriorating as time goes on. The most retentive hitherto tested are various oiled silks, goldbeaters' skin, and some other artificial membranes.

When the large surface which all dirigible shapes expose to the air is considered, it will be seen how important is the choice of material, and that with the best the necessary hydrogen renewal is not a small matter, even if no ascents are made, and may well be more than 1000 cubic feet a day for a moderately large vessel.

Much more than this, however, must be lost when the dirigible is in use. A thousand cubic feet of hydrogen gives a lifting force of about 75 lb., and the engines of one of the larger dirigibles will part with many times this weight in fuel and other ways in less than twelve hours. To keep the vessel at a constant height the lift has to be diminished or the downward force increased at the same rate. While travelling this may be effected to some extent by steering, but when stationary the balance can only be obtained by allowing the equivalent amount of gas to escape. To rise again an equal amount of ballast must be discharged. The number of ascents, therefore, which can be made without a fresh supply of hydrogen is limited by the quantity of ballast which can be carried.

We may now direct our attention to the more promising field presented by true flying machines—machines, that is, which are heavier than air and are supported by the reaction of a downward current of air called into existence by the engines in ordinary flying or by the diversion of natural upward components of the wind in soaring. It is theoretically possible also to maintain flight (without expenditure of work on the part of the flying machine) in a horizontal wind the velocity of which increases with the altitude or varies from place to place at the same level. In this case the flying machine has to descend in the direction of the wind and then turn and ascend against it. In each such cycle work is gained, and the work is obtained from the difference of wind velocities.

One or two examples may be given illustrating the dependence of the power required on the terminal velocity.

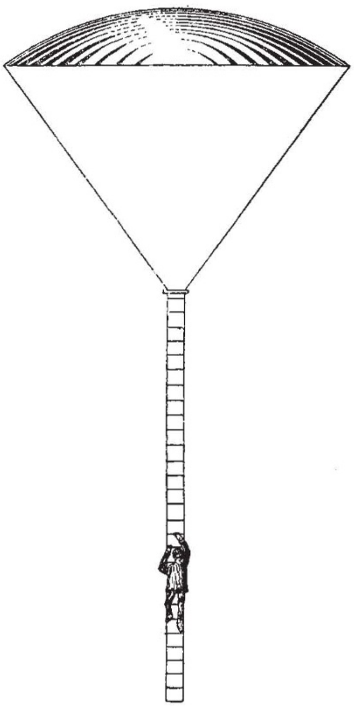

Fig. 1.

First take the case of a parachute, which may be supposed to be massless and to carry a long ladder up which a man climbs (Fig. 1). If the man is to maintain a constant elevation above the ground he must be able to climb as fast as the parachute falls. Now it is known from experiment that a surface such as a parachute experiences a resistance while falling through the air equal to about 14/1000 of a pound for every square foot of area at a speed of 1 foot per second. If we give the parachute a diameter of 36 feet, its area will be about 1000 square feet, and if we suppose the man to weigh 150 lb., the terminal velocity will be given by $v^2=\frac{150}{14}$, or $v=3\cdot 3$ feet per second. This, of course, is much more than a man can do.

If we take a man-power as one-tenth of a horse-power, 55 feet per minute, or, at the outside, 1 foot per second, may be taken as the rate at which he can raise his own weight for any considerable length

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[1] Abridged from the "James Forrest" Lecture, delivered before the Institution of Civil Engineers on April 19 by H. R. A. Mallock, F.R.S.

of time. The area which, when loaded with 150 lb., drops at the rate of 1 foot per second, is $\frac{150,000}{14 \cdot 0}$, or 10,600 square feet, that is, a circle of 113 feet diameter.

With such a parachute a man could by climbing keep himself stationary in the air.

It is not necessary, in order to impart this momentum to the air, that the surface should itself have this area of 10,600 square feet. The same momentum may be given by a much smaller inclined surface moving horizontally.

If a perfectly efficient screw or inclined plane were a physical possibility, there would be nothing to prevent people from flying by their own muscular effort, and it is worth while to examine the causes which prevent the realisation of such a result.

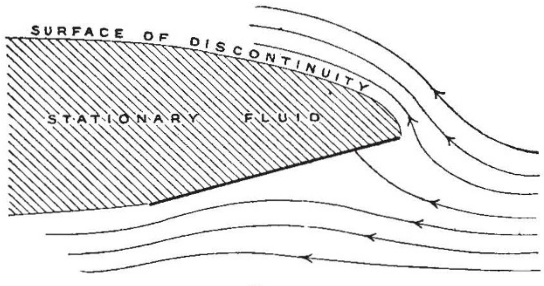


FIG. 2

We will now consider more closely the causes which produce the very marked difference between the theoretical curves given in Fig. 2 and the corresponding quantities as determined by experiment.

It is well known that the fluid with which mathematicians deal, and which is supposed to surround the plane in Fig. 2, is an ideal body which is without viscosity (that is, opposes no resistance to shear), and that in contact with a solid it experiences no frictional retardation.

In such a fluid pressure and velocity are connected by an invariable law, the sum of the potential and kinetic energies of any portion of the fluid remaining constant for all time.

This law, together with the necessary condition of continuity, which for an incompressible fluid merely implies that the volume of a given mass of fluid remains constant, no matter what shape it takes, constitutes the foundation of all the propositions regarding the stream lines of a perfect fluid which have hitherto been worked out, and for such a fluid the stream lines indicated in Fig. 2 are an exact solution of the problem.

Now real fluids differ from the perfect fluid in having both viscosity and surface friction. They require that work should be done if distortion is going on, and they adhere to the surfaces of solids immersed in them. Thus a plane which, if moving edgewise in a perfect fluid, would meet with no resistance, does meet with resistance in a real fluid on account of the adherence of the fluid to the solid surface and the consequent distortion produced in the neighbouring layers of the fluid.

It is true that for fluids such as water and air the viscosity is so small that the direct effects would hardly be noticeable. Indirectly, however, they have immense influence, and it is not too much to say that the most remarkable features in the flow of the winds, tides, and streams are due to the modification of stream-line motion set up by fluid friction and viscosity.

The indirect action referred to depends on the fact that when a stream is retarded by friction the velocity is reduced, although the pressure remains unchanged, and thus the fundamental relation which connects velocity and pressure in a perfect fluid is violated. So long as the stream concerned is of constant section and is neither accelerating nor retarding, as, for instance, when the flow is through a straight pipe of uniform bore, the effect of friction shows itself merely by rendering the stream lines irregularly sinuous, in a way which has not yet been investigated, and as giving rise to a resistance which is proportional to a power of the velocity something rather less than the square, *i.e.* to the 1·85th or 1·9th power.

When, however, the stream is divergent (so that in the absence of friction the velocities and pressures, although constant across each section, change from one section to another, but keep the total energy of the flow across each section the same), the effect of friction and viscosity is much more conspicuous.

On the up-stream side of the plane friction does little to modify the conditions except in the neighbourhood of the edges, but down stream we find, instead of a pond of still fluid, a complex wake consisting of a central current moving forwards towards the plane, bordered by a series of eddies the origin of which is of the same nature as those just referred to in the expanding channel, namely, to degradation of the streams passing round the edges of the plane, which, having insufficient velocity to follow the stream-line path of Fig. 2, are deflected inwards and become involved with the reversed central stream, about half the fluid in each eddy being supplied from up stream and half from the wake.

The eddies are formed periodically, growing to a certain size, and then, breaking away from their place of birth, they form part of the train which borders the wake current. The wake current itself is due to the constant removal of fluid in this way from the back of the plane, and the fact that the outflow from the back has its maximum velocity close to the edge where the composite eddy is being formed shows that the pressure on the back of the plane is lower at the edges than in the centre. Hence it could be stated with certainty, even without any experiment, that the total resistance of a plane must be greater than $\rho v^2 \frac{\pi \sin a}{4+\pi \sin a}$, which assumes that the pressure over the rear surface is uniform and equal to the general pressure at a distance.

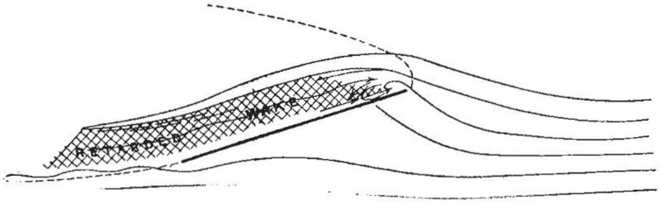


FIG. 3.—Frictional flow: stream oblique to plate.

Experiment, however, is required to determine the actual resistance, and when the plane is broadside to the stream this is found to be about half as much again as the head resistance alone, or about 20 or 25 per cent. greater than the dynamic head × the area of the plane.

When the angle α is small, as it always is in flight, the character of the wake takes the form shown in Fig. 3. Here the wake stream is only recognisable as a reversed current quite close to the plane, and the small eddies as fast as they are formed are so rapidly degraded that after travelling a short distance they are merely recognisable as slight variations in the direction of the general current.

The abstraction of wake water by eddy-making continues, however, even for very small values of α, and has the effect of deflecting the upper boundary of the wake as shown.

The deflection may be considered from another point of view as the outcome of the defective pressure on the down-stream surface of the plane.

This short account gives a general explanation of the observed difference between results calculated for the discontinuous flow of a perfect fluid and those actually found by experiments in air and water, and if the nature of the flow over the back surface were accurately known, the value of α for the maximum of L/R could be predicted. Even in the absence of this knowledge, the assumption that surface friction varies as v^2 and acts only on the up-stream side, leads to a value of α that is not far removed from truth.

Let AB, Fig. 4, be the plane making a small angle α with the stream, and let L and R be the lateral force and resistance which would be experienced if there were no friction.

If L′ and R′ are the same quantities, taking friction into account, and putting Fv^2 as the frictional force parallel to AB, we have $L' = L - F\alpha$ and $R' = R + Fv^2$, and since $L = R_n\alpha$, and $R = R_n\alpha^2$, R_n being the normal resistance Av^2,

$$L' = L - F\alpha = \alpha v^2(A_n - F),$$

and

$$R' = R + Fv^2 = v^2(A\alpha^2 + F);$$

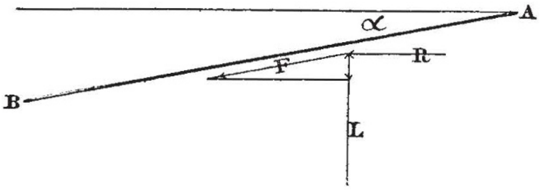


FIG. 4.

hence $L'/R' = \alpha(A - F)/(\alpha^2 A + F)$, and this is a maximum when $\alpha = \sqrt{F/R}$.

Lanchester's experiments make $F/R = 0{\cdot}0075$; Zahn's experiments make $F/R = 0{\cdot}0037$, which correspond to $\alpha = 6{\cdot}5°$ or $3{\cdot}5°$ respectively.

The actual value found from direct experiments on L and R lies between these two, and although 6·5° is nearer the truth than 3·5°, this does not imply that 0·0075 is the more nearly correct value of F/R, for the complete theory must take into consideration the action of the streams on both sides of the plane.

If ascending currents can be found, or if use can be made of differences of speed in the wind at different levels, there is no reason why engineless flight should not succeed, but the opportunities are rather limited.

The heaviest birds which can fly (great bustards, turkeys, and some of the vultures, eagles, and pelicans) weigh between 20 and 30 lb. Of these, bustards and turkeys are short-winged, and the load is more than 2 lb. to the square foot of wing. But their flights are short and their wing movements rapid, and the power expended while rising from the ground must be very great in proportion to their size.

The large birds which make long flights have wing areas giving a load of less than 2 lb. per square foot, and are all adepts at making use of ascending air currents, so that for the most part of their time in the air they have but little work to do.

Much controversy has arisen on the question of the sufficiency of upward currents or upward components of currents of air to account for such flights, but the more the circumstances are examined the more clearly it appears that soaring is in most cases effected in this way, although the origins of the ascending currents are very various. Sometimes they are caused by natural obstructions in the path of the wind, such as cliffs, hills, the sides or sails of a ship, or the slope of waves, but on a larger scale they are chiefly the result of air ascending after having been warmed by contact, direct or indirect, with the ground. At low levels such vertical movements are very small, and at the surface of the ground any motion must, of course, be parallel to the surface; but at considerable heights, especially in sunny countries, these convection currents must always exist, even when the weather is calm, except in the rare event of large tracts of sea or country having the same temperature as the air in contact with them.

To anyone flying at a height, the sense of true vertical which we have, and by which we adjust our balance when standing or moving on the ground, is replaced by the direction of the resultant force of gravitation and any acceleration which the machine may be subject to. In still air or in a uniform wind, acceleration can only be the result of an alteration of level or of the engine speed, and the effects due to the latter cause cannot be very large or rapid. When, however, the machine passes quickly from a region of still air into a wind, or *vice versâ*, which is what happens practically in gusts, the sensation of vertical direction is lost, and although the speed and direction of travel of the machine only change gradually, the resultant of the forces acting on it does so instantaneously, not only in direction, but in magnitude.

The three diagrams in Fig. 5 show the direction in which a short pendulum at the centre of gravity of the machine would point (*a*) when the flight is in uniformly moving air, (*b*) when in an overtaking gust, (*c*) in an opposing gust.

The connection between the angle (θ) which the pendulum makes with the true vertical being

$$\tan\theta = \frac{\text{Propulsive force} - \text{Resistance}}{\text{Lifting force}}$$

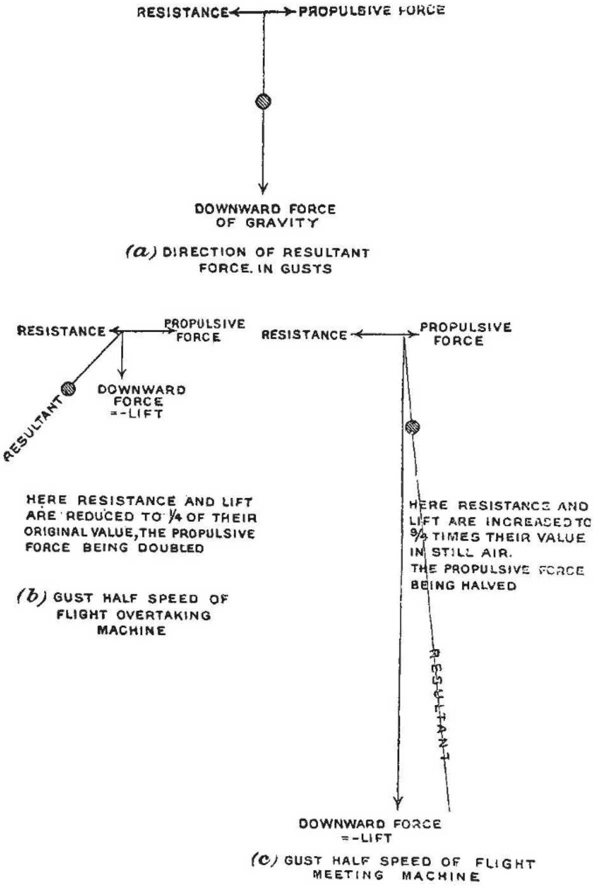
It is hardly to be wondered at that such changes in the apparent vertical should be confusing to the pilot, and that accidents, which are often fatal, should happen while experience is being acquired.

Side gusts may produce still more embarrassing effects, the character of which depends on the class of machine and the disposition of the wings to a greater degree than is the case with gusts in or against the direction of motion.

At the present time the wings and framework of all machines are made as rigid as possible by wire stays, &c., with the result that the breakage of any one part is likely to wreck the whole, and it is probable that as time goes on more attention will be directed to increasing their pliability so as to allow a reasonable amount of distortion without crippling the structure. The problem of determining the greatest possible flexibility which can be given to a structure of a definite shape, size, and weight, which is also to have a definite initial stiffness, is theoretically capable of solution in terms of the strength, density, and dynamic worth of the materials (by dynamic worth is meant the worth which can be stored elastically in the unit volume). and although I am not aware that any case has been worked out, the subject is worthy of investigation.

The most important questions which can be raised about flying machines relate to their stability in flight and the ease or difficulty of starting or stopping them, and on each of these questions I will say a few words. First, as to the theories of stability which have been given from time to time. Some of these I believe to be correct so far as they go, but none of them are anything like complete, since they are all based on the pressures and variations of pressure acting on the up-stream surfaces of wings and omit the variations due to the eddy formation which goes on on the down-stream side.

Before proceeding further, it will be as well to define what I mean by stability in connection with flight. A flying body is stable if, when acted on by a propulsive force and the reactions of the air (but not steered), any small angular velocity imposed about a horizontal axis tends to die out, and any small displacement about a vertical axis to reach a constant value. Or, in other words, any accidental motion of the nature of pitching or rolling must tend to disappear, while an arbitrary twist to the right or left must put the machine on a new, but straight, course.



(*a*) DIRECTION OF RESULTANT FORCE IN GUSTS

HERE RESISTANCE AND LIFT ARE REDUCED TO ¼ OF THEIR ORIGINAL VALUE, THE PROPULSIVE FORCE BEING DOUBLED

(*b*) GUST HALF SPEED OF FLIGHT OVERTAKING MACHINE

HERE RESISTANCE AND LIFT ARE INCREASED TO 9/4 TIMES THEIR VALUE IN STILL AIR. THE PROPULSIVE FORCE BEING HALVED

(*c*) GUST HALF SPEED OF FLIGHT MEETING MACHINE

FIG. 5.

Technically, stability is compatible with the presence of forces which produce increasing oscillations as the result of disturbance; but for the present purpose not only must the average force so called into play be a restituent force, but the disturbing motions must also tend to die out. The oscillations, in fact, must be damped, and not maintained.

None of the flying machines at present in use are stable in the sense in which the word is here used, but in the ordinary conditions of flight the eddies formed behind the wings are small and their period of formation so rapid that the change in the attitude of the wings (that is, in the angle α) which they can produce in one period is inconsiderable, and the stability or instability depends chiefly on the distribution of pressure on the up-stream surfaces, but the case is very different when the machine is passing through variable currents and the angle at which the air meets the wings is liable to large and rapid changes. The alterations in the arrangement of the pressures on the back surfaces are then much greater and take longer to go through their phases—long enough, in fact, to make the process of correction exceedingly baffling.

That flying machines should be unstable in ordinary circumstances is really of very little consequence. The same objection applies to walking. No conscious effort, however, is required to keep upright on *terra firma*, but on the deck of a small vessel in seaway we all know that sea legs are only got by practice, often involving many falls.

The flying machine in gusty weather is much in the same condition, but the falls have more serious consequences.

I think it very unlikely that any type of flying machine will be evolved which, without guidance, will be safe in bad weather, but it is quite possible that the necessary corrections should be applied by an automatic device, and if flight is to be anything but a fair-weather pastime, something of the kind will probably be found necessary.

What is required is an apparatus which will so trim the wings as to keep the machine related in a definite manner, firstly to the true vertical, and secondly to the direction of the resultant force at the time.

The various ways in which this could be done might furnish subjects for several lectures, and I will only say here that the many proposals which have been made to use pendulums or gyroscopes to act directly on the correcting mechanism are certainly bound to fail.

It is essential to the success of any automatic control that the forces called into play to make the corrections of trim should not react on the director of those forces, whether this is a pendulum or gyroscope or any other equivalent device. The only instance in which this condition has been fulfilled is the "steady platform" of the late Mr. Beauchamp Tower. In this Mr. Tower caused a gyroscope (which, in effect, was a pendulum with a very long period) to direct an axial jet of water on a group of openings connected by pipes to a series of rams in such a way that if the openings did not face the jet symmetrically water flowed into one or other of the pipes, and so altered the position of the openings until symmetry was restored, the restituent force having no tendency to alter the direction of the axial jet.

There may be other methods of attaining the same object in the case of wing-trimming or control for flying machines, but any device in which the correcting force tends to alter the position of the corrector is more likely to do harm than good.

The question of stability also becomes important when the flying machine is coming to the ground. In alighting, the machine either has to touch the ground at full speed and trust to retardation, supplied chiefly by the ground, for coming to rest, or it must alter the wing attitude with reference to the path so as to experience a greater resistance for a given lift. This latter method is adopted by birds when pitching on the ground, and in their case at the last moment is generally supplemented by flapping the wings when the velocity is so much reduced that the greatest lift the wing area is good for will not sustain their weight. Birds when pitching on any elevated perch, such as a bough of a tree or a rock, nearly always finish their flight in an upward direction; but neither this nor wing flapping is at present open to flying machines on account of the mechanical difficulties of construction.

Alteration of the trim of the wings, however, presents no great constructional difficulty, but when the angle between the wings and the path is large the effect of accidental variations of pressure due to eddy formation is more serious, and the instability is greater than when the angle in question is the gliding angle; and here, therefore, automatic correction would be very important. If this could be used successfully, a machine the flying speed of which was 40 miles an hour and which had a gliding angle of 1/7 could, as may be found from the resistance diagrams, reduce its velocity by alteration of the trim of the wings to 25 miles per hour before the weight ceased to be air-borne. Further, since for the whole time the resistance would average about one-fourth of the whole weight, the time taken in effecting the reduction of speed would be four times that required for gravity to generate the difference between 40 and 25, being 15 miles per hour. During this time—2·7 seconds—the average speed would be 32 miles per hour, and the machine would cover about 120 feet. These rough figures can be easily corrected from the curves giving lift and resistance for any particular machine, but there can be no doubt that it would be a substantial gain if the high speeds, which are becoming more and more common, could be quickly and safely reduced before reaching the ground.

It is quite possible to imagine a flying machine made with lifting screws which would rise vertically from the ground and remain poised and stationary in the air; but no success has hitherto attended any attempts in this direction, partly because the inventors have not realised the very large blade area necessary for reasonable economy of power. One way of realising the stationary condition would be to connect two flying machines travelling at the same speed in opposite directions with a length of rope and letting them circle round one another. No "banking" would take place, as the centrifugal force of each would be taken by the pull of the rope. If the latter were shortened as far as possible, the pair would, in effect, form a single machine with a lifting screw. The experiment would be dangerous, and is not recommended for trial, but is mentioned rather as indicating the size of the screw blades which the hovering type of machine would require.

In taking a general view of the present condition of the art of flying, it must be admitted that much remains to be done before it ceases to be a fine-weather sport, and I think the right course to pursue would be to try to evolve a type of machine which is fairly safe even in turbulent winds, and can arise and alight on the smallest possible area. When the essential features of the design which secures these results are recognised, the machines may be specialised for war or other purposes, and additional improvements may be introduced for convenience, comfort, or speed.

The opinion seems to be gaining ground that flying machines are more likely to be usefully developed than dirigible balloons, and in this opinion I fully concur, more especially as regards the larger dirigibles, which I have always considered too frail and too liable to accident to be of much real service.

All aircraft, whether heavier or lighter than air, will for some time to come be designed for the purposes of sport or war rather than for commerce, and although for war-machines cost takes a second place, it must be remembered that a dirigible costs rather more than a torpedo-boat, whilst a flying machine costs rather less than a torpedo. Further than this, there are very few services to be performed by a dirigible which could not be carried out as well, or better, by a flying machine, the only, and rather dearly purchased, advantages attaching to the balloon being its power of rising quickly and of leaving the ground without the necessity of taking a run; and I think the best policy for us would be, while recognising the occasional usefulness of dirigibles of moderate size (and building a sufficient number for experiment), to devote our attention chiefly to the elaboration of the most efficient means of destroying them.

From the purely scientific point of view it cannot be said that the ascents of any large balloon have added much to our knowledge.

The small balloons, however, recently used for carrying self-recording instruments have ascended to heights (60,000 feet or more) at which personal observation is impossible, and have brought back valuable information which could scarcely have been attained in any other way; and although the records, as a rule, only deal with pressure and temperature, there is no reason why solar radiation should not also be measured by suitable apparatus. Such measures would give a better knowledge of the temperature of the sun than could be got by direct observation, even on the highest mountains.

In conclusion, and speaking generally, I may say that it seems desirable to encourage experiment on the widest scale, even if much of the work is not on strictly scientific lines; bearing in mind that great improvements may result from the working out of ideas which, as originally conceived, were unsound or even absurd, and that this is the more likely to be the case in such a subject as flight, for which, as I have endeavoured to point out, a considerable part is not yet subject to accurate theoretical treatment.

APPENDIX.

The relative densities of different gases at the same altitude may be conveniently expressed in terms of heights of homogeneous atmosphere of each.

The height of the homogeneous atmosphere for a gas is defined as the height of a column of the gas of uniform density (equal to that which it has at sea-level) the weight of which produces the atmospheric pressure at its base. Thus the height of the homogeneous atmosphere H_a for air is in feet the number of cubic feet which weigh 2100 lb. nearly, and since 1 cubic foot of air weighs 0·080 lb., $H_a = 26{,}000$ feet nearly.

For hydrogen $H_h = H_a \times$ the ratio of the densities of the two gases (namely, 16), so that $H_a = 416{,}000$ feet nearly.

If the distribution of temperature in the atmosphere is isothermal, the actual height (h) above sea-level at which the pressure is p is $h = \mathrm{H} \log \frac{p_0}{p}$. Thus when $h = \mathrm{H}$ the pressure is p_0/e, and the pressure does not vanish until an infinite height is reached.

If, on the other hand, the temperature decreases according to the adiabatic law (that is, if the temperature of the air at height h and pressure p is what it would be if with surface temperature to start with it was lifted without loss or gain of heat to the given height),

$$h = \mathrm{H}\frac{\gamma}{\gamma - 1}\left(1 - \left(\frac{p}{p_0}\right)^{\frac{\gamma-1}{\gamma}}\right), \text{ or } \mathrm{H}\frac{\gamma}{\gamma - 1}\left(1 - \left(\frac{\rho}{\rho_0}\right)^{\gamma}\right).$$

In this case, therefore, there is a definite upper limit to the atmosphere, for when $p = 0$, $h = \mathrm{H}\frac{\gamma}{\gamma - 1}$ (rather more than 17 miles for air and 275 miles for hydrogen).

What the actual limit of the atmosphere may be is not known, but experiment shows that for the lower strata, at any rate, the adiabatic distribution of temperature is not very far from the truth.

If we have two short columns, one of hydrogen and one of air, of the same length, and both at height *h*, then (putting $H\frac{\gamma}{\gamma-1}=K_a$ for air, K_H hydrogen, and N for the ratio of the densities, ρ_a/ρ_H at sea-level, the density of the air at h is $\rho_a(K_a-h)^{1/\gamma}$, and of the hydrogen $\rho_H(K_H-h)^{1/\gamma}$.

If the balloon carries no weight it will ascend until the densities are equal, which occurs when

$$h=NK_a\left(\frac{N^{\gamma-1}-1}{N^{\gamma}-1}\right),$$

or, since $N=16$ for air and hydrogen, and $\gamma=1{\cdot}41$, $N^{\gamma-1}=3{\cdot}1$, $N^{\gamma}=51$, and $K_a=17$ miles,

$$h=\frac{16\times17\times2{\cdot}1}{50}, \text{ or } 11{\cdot}5 \text{ miles},$$

and no hydrogen-filled balloon could ascend higher than this if the temperature was the adiabatic temperature.

The ascents of the balloons with recording instruments, however, lead to the belief that at heights exceeding 6 or 7 miles the temperature is constant, or nearly so, so that the practicable height of ascent may very considerably exceed the 11·5 miles just mentioned.

UNIVERSITY AND EDUCATIONAL INTELLIGENCE.

CAMBRIDGE.—The General Board of Studies will shortly proceed to the appointment of a Stokes lecturer in mathematics, in succession to Mr. J. H. Jeans, who is resigning the lectureship. The appointment will be from June 24, 1912, to September 29, 1913. The annual stipend is 200*l*. Candidates are requested to send their applications, with a statement as to the branches of mathematics on which they are prepared to lecture, and with testimonials if they think fit, to the vice-chancellor on or before May 22.

DR. A. H. GARDINER, Laycock student of Egyptology at Worcester College, Oxford, has been appointed reader in Egyptology in the University of Manchester.

REUTER reports that the King of Siam has sanctioned a scheme for the establishment of a University of Bangkok. There will be eight faculties, including medicine, law, engineering, agriculture, commerce, pedagogy, and political science.

THE annual conference of the Association of Teachers in Technical Institutions will be held at Whitsuntide in London, at the Polytechnic, Regent Street. A paper will be read by Sir Alfred Keogh, K.C.B., on "The Relations between the Imperial College of Science and Technology and Technical Institutions." There will also be a discussion on the important question of the cooperation of employers in technical education, following a paper on this subject by Mr. E. A. Atkins.

THE Bethnal Green Free Library, one of the pioneer institutions of the free library movement in Great Britain, has now completed thirty-six years of work without endowment or State aid. We are informed that a million readers, borrowers, and students have used the library and attended the classes in connection with it. A plan is now on foot to secure the perpetuity of the work, and a reserve fund of 10,000*l*. has been started, to which the King has contributed. Donations may be sent to the treasurer, Mr. F. A. Bevan, 54 Lombard Street, London, E.C.; the bankers, Messrs. Barclay and Co., at the same address; or to the librarian, the Free Library, Bethnal Green, London, E.

IN the House of Commons on May 6, Mr. Runciman said, in reply to a question relating to agricultural education:—"I am carefully considering by what means the various agencies, actual and prospective, for the provision of agricultural education and research and of technical advice in agriculture may most effectively be brought into cooperation. I think it will probably make both for efficiency and for economy if county councils and agricultural colleges will combine for the purpose of joint action in respect of many of their agricultural activities. I am not yet, however, prepared to make a definite statement on the subject, as to which I shall hope, before taking any decision, to learn the opinions of county councils and agricultural colleges."

THE University of Chicago has established a system of retiring allowances for professors or their widows. A fund of 500,000*l*., says *Science*, taken from the 2,000,000*l*. Rockefeller gift of 1910 has been set aside for this purpose. This pension system will grant to men who have attained the rank of assistant professor or higher, and who have reached the age of sixty-five and have served fifteen years or more in the institution, 40 per cent. of their salary, and an additional 2 per cent. for each year's service over fifteen. The plan also provides that at the age of seventy a man shall be retired unless the board of trustees specially continues his services. The widow of any professor entitled to the retiring allowance shall receive one-half the amount due to him, provided she has been his wife for ten years.

THE University of the Philippines has, we learn from *The Manila Times* of March 7 last, conferred the honorary degree of doctor of science upon Father Jose Algue, director of the official weather bureau of the Government of the Philippine Islands. Dr. Algue, who was born in Manresa, Spain, in 1856, was in 1891 appointed assistant director of the observatory in Georgetown, D.C. In 1894 he became assistant director of the Manila Observatory, conducted by the Jesuit fathers, which in 1901 was made the official bureau. He held this position until the death of its founder, Father Faura, in 1897, when he was appointed director. Father Algue reorganised the meteorological service of the institution and perfected a system whereby the observatory receives daily telegraphic report from over thirty meteorological stations in the islands, ten in Japan, six in Formosa, four on the Chinese coast and three in Indo-China. He is a leading authority on earthquakes, and his observations in the Philippines, where seismographic phenomena are of such frequent occurrence, have been of great service. The University of the Philippines confers but one honorary degree each year, and its scroll at present bears only the names of Dr. Algue and one other honorary doctor.

THE experienced instructor appeals in teaching to as many of the pupil's senses as possible. The eye, for instance, is being more and more pressed into service to assist the ear in its work, and good lectures and school lessons are consistently illustrated by pictures and diagrams. The most recent of these pictorial aids is provided by the kinematograph, and it is satisfactory to learn that manufacturers and dealers are taking active steps to familiarise lecturers and school teachers with the possibilities of kinematography in increasing the value of their work as well as simplifying it. The proprietors of *The Bioscope*,