CHAPTER I

GENERAL PRINCIPLES

THE conquest of the elements around him is, and ever has been, one of the objects for which man is continually striving. He early learned to support himself in water and to move rapidly over its surface, but the emulation of the birds, though dreamed of since the days of Dædalus, has only of recent years become an accomplished fact. And now, when the subject of artificial flight is so much, literally and metaphorically, 'in the air,' when each day's newspaper has its account of some new record made, or old record broken, an elementary account of the principles underlying artificial flight, and the main types of machine in common use, may prove useful to those readers who are not content to take facts as they stand, but wish to know something both of the 'why' and the 'how' of those facts.

It is however, impossible, to demonstrate clearly these principles without some knowledge of the fundamentals of mechanics, and as an exposition of the points which chiefly concern us will, in the future, save much circumlocution, we give them here by way of preamble.

We shall constantly use the term 'force,' and since in aeronautics, as in all scientific work, it is of primary importance to avoid looseness of terminology, we follow Newton's example, and define the term 'force' to mean 'that which alters, or tends to alter, a body's state of rest, or uniform motion in a straight line.'

If, then, any body under consideration be either in a state of rest, or moving with a constant speed, we infer that no forces are acting on it. If, on the other hand, its speed is varying *either in magnitude or in direction*, we infer that some force is acting on the body and causing this variation. The importance of the phrase which we have just emphasised will be made apparent in the sequel.

Now, in order to specify a force completely, we require to know both its magnitude and its direction. A force equal to the weight of 10 lbs. acting in a northerly direction is very different from a force of 10 lbs. weight acting in an easterly direction, for the one will urge the body on which it acts towards the North, the other towards the East. Bearing this in mind, we see that we can graphically depict any given force by means of a straight line, the length of the line, on some appropriate scale, representing the magnitude of the force, and its direction the direction of the force. Thus in the diagram, the line AB may be taken to represent a force of 10 lbs. weight acting to the North, the line AC a force of 8 lbs. weight acting to the North-East, and the line AD a force of

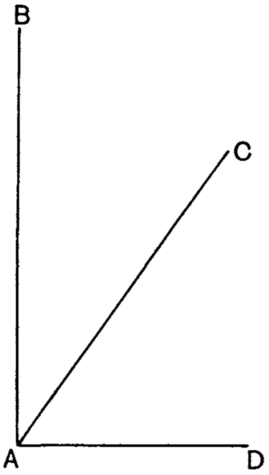

Fig. 1.

5 lbs. weight acting to the East. Now, if only one force be acting on a body, that body will move with ever increasing speed in the direction in which the force is acting. But supposing that at some particular point of a body we have *two* forces applied; how will

the body move under these circumstances? The answer is given by a very simple construction, which the reader is asked to bear carefully in mind, as we shall continually make use of it. Suppose A to be the point in the body at which the two forces are applied, and let the magnitude and direction of action

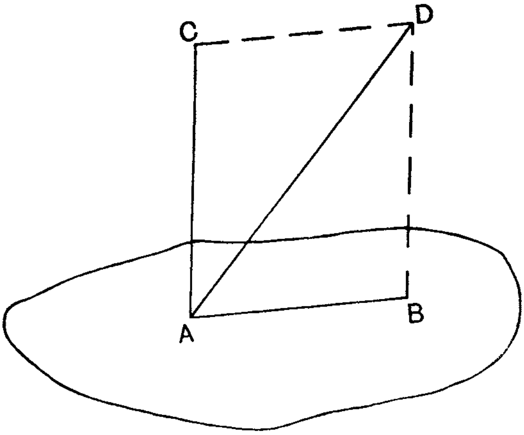

Fig. 2.

of one force be represented by the line AB, and of the other by the line AC.

Draw the dotted line CD parallel to AB and BD parallel to AC, so that these two lines meet at D. Draw the straight line AD. Then the body will move in the direction AD, and its motion will be such as if a *single* force of magnitude AD were acting on it. (AD will be drawn on the same scale as AB and AC.) And *vice versa*, any *single* force such as AD acting on a body can be split up into *two* forces such as AB and AC, and the effect of each of these forces studied separately. In scientific terminology, AD is called the *resultant* of the forces AB and AC, and the forces AB and AC are called *components* of the force AD.

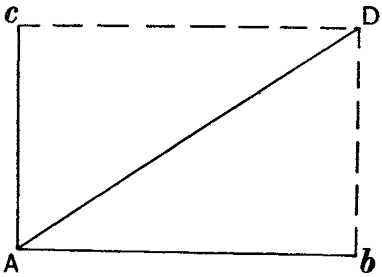

Fig. 3.

It is pretty clear that a force such as AD can be divided into two 'components' in any number of ways, for any number of parallelograms can be drawn having AD as diagonal, but when the parallelogram becomes a rectangle, as in Fig. 3, then Ab and Ac are called, *par excellence*, *the* components of the force AD, and whenever we use the phrase '*the* components' it will be with this signification.

Now let us study in some little detail the motion of a body which is acted on by several forces. Suppose, for example, we have a body acted on by two vertical forces P and Q, one acting upwards, the other downwards, the points at which these two forces act being in a vertical line. Then the actual force—

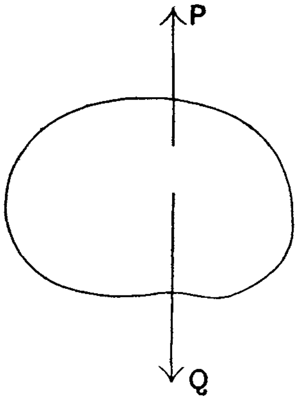

Fig. 4.

the *resultant* force—on the body will be a force equal in magnitude to the difference between P and Q, and the body will move upwards or downwards according as P is greater or less than Q. If P be exactly equal to Q, then, of course, the body will be in equilibrium.

It is important to notice, also, that unless the points at which the two forces act are in a vertical straight line, the conclusions which we have just reached will no longer be valid. If the two forces, which we will suppose to be equal in magnitude, act as shown in Fig. 5, then, so far from the body being in equilibrium, it will turn round in the direction

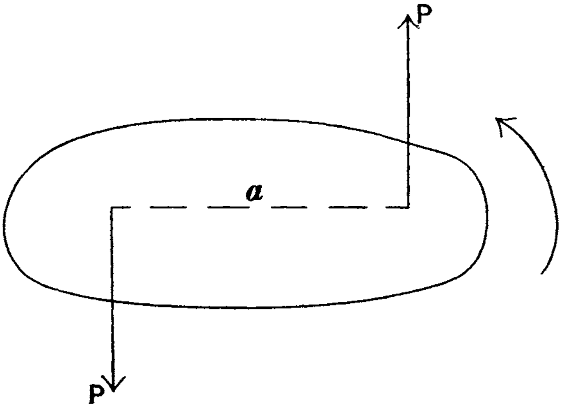

Fig. 5.

indicated by the arrow, and the correct magnitude of this turning tendency is measured by the product of one of the forces into a, the perpendicular distance between the two forces. In fact the two forces together constitute a turning system, which is known as a 'couple.'

At this juncture it is advisable to say a few words about the famous 'Third law of motion' first enunciated by Newton. It may briefly be expressed thus—'To every action there is an equal and opposite reaction.' For example, if we press our hands upon a table, the table exerts an equal and opposite force on our hands. If a horse in pulling a cart exerts a definite force upon it, the cart exerts an equal and opposite force upon the horse. This equality of action and reaction has been made an occasion for a well worn and somewhat absurd puzzle-question—'Why, if these two forces are equal, do the horse and cart ever get into motion at all?' The answer is obvious. In dealing with the motion of any body, we must ask ourselves what are the forces acting on that body, *and on that body only*. The sum of these forces when added, or compounded, in the manner shown above will, in general, be a definite force acting in a definite direction, and the body will move in that direction with ever-increasing velocity. Now, returning to our problem of the horse and cart, the forward pull of the horse is exerted *on the cart*, whilst the backward reaction of the cart is exerted *on the horse*, and has nothing to do with the motion of the cart itself. It is, indeed, a fact which is often lost sight of, that all forces consist of *stresses* between two material bodies, and the Newtonian mode of estimating forces tends to fix attention on one aspect only of the stress.

And now, leaving these somewhat tedious, but very necessary, introductory principles, let us see how they may be applied to the elucidation of aeronautical problems.

Before we can propel ourselves through the air, we must first be able to rise into the air, and as is well known this latter problem is solved by the use of two types of machine—the heavier-than-air machine, and the lighter-than-air machine. The kite is a representative of the former class, the balloon of the latter.

Let us deal with the latter type first, and seek an answer to the question 'Why does a balloon rise from the ground?'

Long before a balloon ever did rise—2000 years ago—the answer was supplied by Archimedes, who showed that when a solid is completely immersed in any fluid, it experiences an upward thrust which is equal to the weight of fluid displaced.

Think, then, of a solid substance immersed in a fluid such as water. Two forces act on it—its weight Q in a vertically downward direction (see Fig. 6), and the upward force or thrust P, which by the principle of Archimedes is equal to the weight of fluid displaced.

Now if the solid, volume for volume, be heavier than the fluid, Q will be greater than P; the resultant force will therefore be downwards, and the body will sink. If the solid be specifically lighter than the fluid, P will be greater than Q and the body will rise to the surface, while, if the solid and fluid have the same specific gravities, the solid will rest indifferently in any part of the fluid.

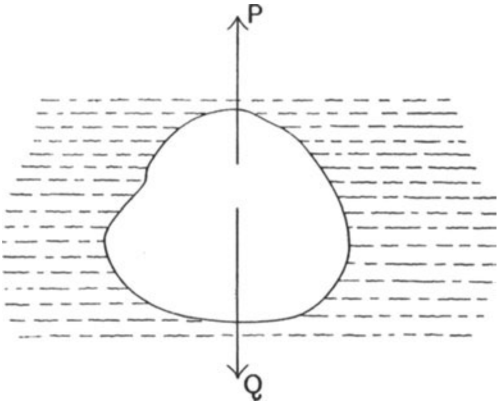

Fig. 6.

And this gives us the reason why a balloon rises in the air. A cubic metre of air, under standard conditions of temperature and pressure, weighs 1·293 kilogrammes. A cubic metre of hydrogen gas under similar conditions weighs only ·088 kilogrammes; if then we take a light but gas-tight envelope of some kind and fill it with hydrogen gas, so as to form a balloon of say 1 c. metre capacity, the balloon will