GYROSTATIC ACTION.

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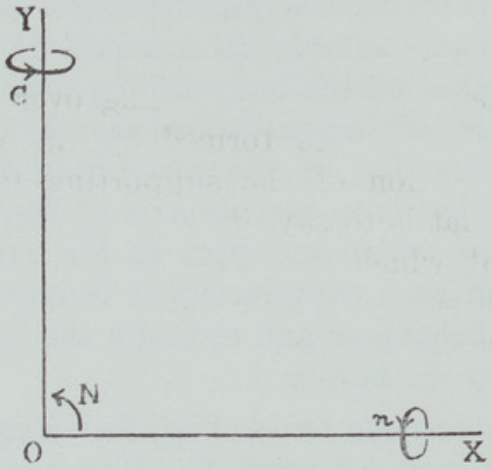
Everyone is familiar with the peculiar stability acquired by a boy's top or a hard boiled egg when set in rapid rotation about its axis of symmetry. In such experiments gravity appears unable to lower the centroid of the body as it would do if the rotation were non-existent. Instead of the body falling over under the action of the couple or pair of forces formed by the weight of the body and the upward reaction of the supporting table or ground, the body "precesses," that is to say, its axis of figure has a slow conical motion, the rate of which increases as the rate of spin decreases. In connection with such experiments it is important to realise first the cause of this behaviour and secondly the various ways in which it comes into play in nature.

In a collision between two bodies, the impact depends upon the momentum of the bodies concerned. Momentum depends upon the velocity and the mass of the moving body. It has been called "quantity of motion," a term which, while scientifically undesirable, still conveys the general idea of what is meant. The momentum of a body can be altered by changing its velocity. Velocity, in turn, may be altered by changing its magnitude, or its direction, or both. Thus the velocity of a man running at constant speed round a circular racecourse is constantly altering. At one instant his velocity may be ten miles an hour northwards, at some later instant it will be ten miles an hour southwards—a very different thing. To alter velocity force is necessary, whether the velocity be altered in magnitude, in direction, or in both. Thus when a stone attached to a string is whirled round at constant speed in a circle, the change in its velocity (as regards direction) is supplied by the action of a force (the tension) transmitted through the string to the stone. Conversely, if a force is free to act on a moving body, the velocity of the body will be altered in magnitude, in direction, or in both.

When we deal with rotating bodies, we have to consider not momentum (as in onward motion), but what is called angular momentum. This quantity depends upon the rate of spin and upon the mass and the arrangement of the matter of the body. The angular momentum will be altered if either the rate of spin is altered or the direction of the axis of spin is altered, or if both be altered. To alter this angular momentum about the axis of

spin, the application is necessary of forces which have leverage (that is, which could produce turning) about the axis of spin. Similarly the free action of such forces about *any* line passing through a rotating body must produce change of angular momentum about that line, either by altering the rate of spin of the body, or by altering the direction of the axis of spin, or by altering both.

Let OX be the direction of the axle of a flywheel, the wheel spinning counter-clockwise as seen by an observer looking in the direction from X towards O. Let now the axle be subjected to the action of forces tending to raise O above and to depress X below the plane of the diagram—that is the forces have counter-clockwise



leverage about YO. Then the action of the forces is to generate angular momentum about OY, not by altering the rapidity of spin about the axle, but by turning the axle from the position OX towards the position OY. If the axle is pivoted at O it will "precess" or rotate round O in a counter-clockwise direction as seen looking down on O. Note that the forces do not turn the axle out of the horizontal plane as they would do if the flywheel were not spinning: their action is merely to cause motion about a vertical axis through O, which axis is at once at right angles to the spin axis OX and to the couple axis OY, as the axis about which the forces act is called.

Conversely, if the axle of the spinning body lies along OX, and is turned towards OY, forces forming a couple must be applied round axis OY. If I is the moment of inertia of the body, n the rate of spin in radians per second, N the rate of turning from position OX towards OY, the magnitude C of the couple is given by $C = InN$ in absolute units. Or if n and N are taken in revolutions per minute, we have $C = InN/2940$, C being now in engineers' lb. wt.-foot units.

Such gyrostatic couples are common in nature, and arise in every case where the direction of the axle of a rapidly rotating body undergoes alteration. Examples are seen in the turning of

a motor car (with its heavy flywheel) round a corner, the pitching of a steamer fitted with fore and aft turbines, the alteration of the line of flight of an aeroplane, the turning round of an electric crane having a rapidly rotating motor armature, the passage of a train with its many wheels round a curved railway track. In all these cases the above formula is applicable, and enables the magnitude of the forces involved to be calculated.

It will thus be seen that the simple experiments of spinning a top or an egg have as their basis one of the most important of dynamical principles, and one which must be carefully investigated in connection with many problems of practical engineering.

[A large number of experiments were shown to indicate the nature of the gyrostatic action set up in the cases mentioned in the paper and in others, and deductions were drawn as to the probable effects of such action.]