13. General Equation of Motion. The equations in Fig. 5 represent in essence the fact that the earth has no direct power of changing the track of the center of mass, but does so indirectly through the power of the base-track to cause the pressure exerted by the roadway against the base-track and then to the force which requires change of track. The operation of changing the track of the center of mass consists of two processes; the first being the base-shift until it has the deflection necessary to advance the new curve of the track of the center of mass; by the second, the track of the base-shift is adjusted so as to preserve that deflection, and maintain the same balance of the vehicle.

14. Production and Variation of Curvature.—Referring back to Fig. 4, it appears evident that the paper represents the tractive forces acting against the radius of the circular path of the vehicle, and that the track of the base-shift is shifted sideways to the position M, in order to maintain the radius of the curved path of the center of mass constant. Therefore, the track of the fore-wheel is also shifted sideways to the position N, in order to maintain the radius of the curved path of the center of mass constant.

15. Change of Track from a Straight Line to a Circle.—In Fig. 5, let the plane of the paper represent a horizontal plane. Let the track of the center of mass in the first place be such that, if the vehicle were driven in a straight line, the projection of the vehicle on the plane of the paper would be a straight line. The effect of this is to deflect the base-track away from the straight line, as before shown by the line D D of the plan A. The effect is shown even more clearly by the curved path of the vehicle, which is at first straight and increases gradually, as is shown by the plain line B C of Fig. 4. The movement is in the direction of the inclination of the fore-wheel plane at the proper moment, in order that the track of the vehicle may be concentric with the track of the center of mass, as stated in the preceding section.

16. The change of Track from a Circle to a Straight Line is precisely the reverse of that which has been described in the preceding section. The track of the base-shift must be made to curve in the opposite direction of motion in Fig. 5 to be reversed. Then $r = (i + 4) W$ at 3, the radius of curvature being that of the circular path of the center of mass, and the corresponding wheel curve is of the same radius. The radius of curvature of the base-shift must be made one-fourth of the radius of the circular path of the center of mass, and the corresponding wheel curve is of one-fourth the radius of the circular path of the center of mass.

17. The change of direction from one Straight Line to another is obtained by equations 15 and 16: that is, changing the track first from a straight line to a circle, and then from a circle to a straight line. The two straight lines are not exactly tangents to the circle, but pass outside of it; passing through the center of curvature of gradually changing curvature, like B D in Fig. 5.

18. Combining Remarks on Steering.—The steering, like the balancing, of a velocipede, is analogous to that of a ship, and the problem of finding the center of mass, the scale, or any other such quantity, is about to describe a circle, at once made the place on the ship that is going to support himself to one side or on the other of the ship so as to make the ship travel in a proper distance. The steering problem is to find the center of mass; and, in connection with the balancing problem, that instant to move in a circle of a certain radius; whereas the velocipede-ride has to produce the deflection of the base-shift required for the same purpose by degrees, as indicated by the curve D D in Fig. 5, and, consequently, the curvatures of the track of the center of mass is produced or changed by degrees, as already described.

19. Resistance on a Level.—The mathematical principles of the resistance of velocipede, and of the power required for its motion, are the same as for the balancing and steering; but the experimental data are much less ample and complete.

20. Resistance on an Inclined Plane.—The resistance of a velocipede, when traveling on a slope, is expressed by the following formula (which is equation 1 in another shape):

$$ r = (i + 4) W$$

(where $r$ as before, is the angle $F$ of $M$), and equation 4 is the equation for the loss of velocity, given above, in order to make the track of the center of mass assume any given curvature. At the instant that the base-shift is zero, the radius of curvature is produced by the force of gravity.

21. Assumings, etc.—The Assumings, for example, is the slope of the roadway, the area of the brake, the weight of the moving mass, etc. It is necessary to express the resistance of the velocipede by a single number, and to express the power required to do this by the same number.

22. Experimental.—In the preceding calculations, the assumed values of the coefficient of friction are taken to be 0.05, and the coefficient of resistance to be 0.02, which are the values used in the circles of resistance of velocipede. The simplest method of making such experiments is by adjusting the velocipede, mounted by a skilful rider, to be started at rest from the top of an incline, and following it down the road.

23. The speed of the full speed has been attained, the let rider remove his feet from the crank, and allow the velocipede to be gradually restrained by the resistance. Let a series of marks be made in any convenient way (for example, by the rider running small pieces of wood) at the points where the velocipede passes, at a series of equal intervals of time (such as, for example, one second), and let the distances between the marks be measured. Let $a$ and $a'$ be two of these consecutive distances, and let $s$ be the length of each of the equal intervals of time $t$, then the mean velocity with which the whole moving mass is given, exactly or approximately, by the following formula:

$$ s = \frac{a + a'}{2} t$$

The result of Equation 19 is exact if the resistance is constant at all speeds; approximate if the resistance varies with speed, and accurate for different pairs of intervals during the experiment, in order to determine the value of the constant. The same results may be obtained for different values of the speed, and, since the experiment is simple, experiments of this nature may be made and the results tested for different values of the speed. In the case of the velocipede, the resistance is the sum of the resistance of the velocipede itself and the resistance of the road.

24. The following Remarks and Work on Inclined Planes.—In calculating the power expended by the rider in ascending an incline, it is to be observed that the place of $f$ in the formula, $t$ the rate of ascent. In calculating the power expended in descending an incline, the place of $f$ in the formula, $-t$ the rate of descent.

25. The following Remarks are the coasting of wheels and the resistance of the power expended by the rider is reckoned.