point of the rolling body is at rest only with reference to this moving line. As one stands aside and views both, the contacting has precisely the same motion as the moving line. But if on the moving line, then he sees the lowest point of the wheel absolutely at rest for its instant of contact.

But suppose that one takes his position at the center of the wheel. The highest point of the wheel will appear to be moving forward in the direction *C*, while the lowest point will seem to be moving in the opposite direction. In fact, *with reference to the center* the particles of the wheel will have a movement of rotation.

There are thus two rotations going on all the time. The entire rolling body rotates *for the instant of contact* about the point of contact. This center of rotation is constantly changing, however. The central particle of the rolling body, on the other hand, always remains a center of rotation.

Further, if there is a second contacting surface, as in Fig. 2—this second surface effecting the driving of the circle—then *relatively to this moving surface* there is for the moment of contact a center of rotation. This instantaneous center of rotation—the upper point of contact—moves backward relatively to the driving surface.

Much the same may be said in reference to straight and tapered rollers in a roller-bearing. There is a central line consisting always of the same particles, and relatively to which all the remaining particles rotate as about an axis. It is the *axis of rotation.* Then, diametrically opposite each other, are two lines of contact. Each of these is an instantaneous axis of rotation, quiescent for the moment of contact but immediately succeeded by another. Thus in Fig. 3, the line *D E* is the axis of rotation. In the body of the roller, the particles of material along this axis are such that, if they be regarded as quiescent, every other particle will be seen to rotate about their line of distribution. The lines of contact of the roller with the race ways are the two instantaneous axes of rotation.

The motion of each of the particles of the wheel, Fig. 1, is the compound of two distinct movements—(1) motion in a direct line, given by the arrow *C*, and (2) motion of the point as it rotates about the center of the wheel. Both uniform, we see that at *B* both motions are in the same direction, while at *A* the directions are the opposite. Further, as learned, there is no motion of a particle at the moment of rolling contact. So, then, at *A* the velocities of the contrary motions must be the same in order to produce this quiescence. We have now arrived at a most important principle—the forward velocity of a rolling body is just equal to its peripheral velocity. And, further, since at *B* both are in the same direction, we have the principle that the velocity of the point of the periphery furthest removed from the point of contact is just double the forward velocity. So that (Fig. 2) the velocity of the driving surface *K* is double the forward velocity of the driven circle. These are most important propositions, and are true whether the plane of rolling is perpendicular or inclined to the surface upon which the rolling is done.

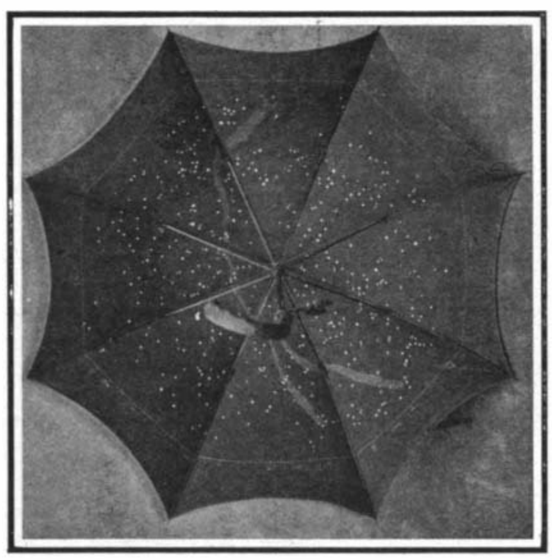
Without going into the mathematical proof, it may be stated that, in consequence of principles already enunciated the axis of rotation and the two instantaneous axes of rotation are three lines meeting in a point. Further, if the rolling bodies are balls or rollers revolving about a shaft, then the axis of this shaft must pass through this point of intersection. Thus, in Fig. 3, these four lines all meeting in one point are *DH, DE, DF, DJ.*

In ball and roller-bearing design, this requirement becomes of first-rate importance. Thus the four-point ball-bearing shown in longitudinal section in Fig. 4 is correct in design in so far as the convergence of these four lines are concerned. But some may have difficulty in seeing that a rolling ball has an instantaneous axis of rotation as well as a roller. Reflect, then, that both the points 1 and 2 of the ball in Fig. 4 are absolutely at rest for the infinitesimal moment of contact. They determine, therefore, a line of quiescence equally with a roller. Similarly, the points 3 and 4 are at rest relatively to the driving ball-race—and determine a second instantaneous axis of rotation.

In Fig. 5, the instantaneous axis of rotation determined by 5, 6, intersects the axis of the shaft at *O.* This gives *OC* for the axis of rotation. Similarly 7, 8 yield the line *QC* as the axis of rotation. We have, therefore, two conflicting axes of rotation. The design of the bearing is consequently incorrect.

The friction arising from compression is an important matter. In Fig. 6 *GK* is one of the instantaneous axes of rotation. The ball is flattened by compression at the points of contact, the one region of contact being represented by *FD.* At the instant of contact the ball is rotating on *GK* as an axis. This means that every point along *FD* is rotating in a plane perpendicular to *GK.* The result is that all along *FD* there is a sliding taking place relatively to the race way. The point *D* is moving in a circle whose center is *C* and radius *DC.* There is, then, sliding friction, effective over the whole area of compression. The pressure corresponding to the slide is in the direction *GK.* The seriousness of the friction, then, is dependent upon the pressure in this direction. The size of the compression is due to the pressure perpendicular to *FD.* By suitably designing the race ways, the pressure in the direction *GK* may be made small, although it may be unavoidable to keep large that in the direction perpendicular to *FD.* The way to do this is to diminish the angle *DBC.* A design such as that shown in this figure (6) is to be condemned on account of the large size of this angle between the race way and the instantaneous axis of rotation. In Fig. 7 a correct design is shown. If we observe in Fig. 6 that *AHB* is an isosceles triangle, we readily see that angle *DBC* is one-half the supplement of the angle of the groove *AHB.* Consequently, if we desire to make *DBC* small, we see to it that *AHB* is large. Thus, by making $AHB = 170$ deg., the angles between the instantaneous axis of rotation and the faces of this race way are reduced to 5 deg. each. For such angles the pressure in the direction of *GK* is well-nigh negligible. This means that the sliding friction due to compression is practically eliminated.

A further question that arises in designing ball and roller bearings relates to the use of separators. In Fig. 8, it will be readily seen that at the point of contact between two balls (or rollers) there is a slide, the surfaces in fact moving in opposite directions. The question arises: Should balls be prevented from mutual contact so as to eliminate this source of sliding friction? To answer this it is necessary to know whether the slide occurs under pressure. For, despite the slide, the friction would be negligible if there is little or no pressure from ball to ball. The writer has made a very complete mathematical inquiry and found that balls and rollers probably do press upon each other with a considerable percentage of the load, so that separators are to be regarded as advisable. If used, however, they should be rolling separators. The introduction of a non-rolling separator will not result in eliminating sliding friction. But by properly using a rolling body—a ball or roller—this friction may be avoided. Fig. 9 shows that the small separator ball is competent to partake of the contrary motions of the bearing balls.



A CURIOUS STAR MAP.

The position of the separator should be noticed, as no other position seems allowable. The center of the separating ball should be in the straight line joining the centers of the bearing balls which it separates. For if it be located above or below, the pressure of the bearing balls will force it out or in. In either case, a new source of friction will arise from the rotation under pressure of this ball against parts of the bearing.

To hold the separator in place, some suitable means is required. The separating ball will of course rotate against the holder. But what is important is the fact that this rotation occurs without pressure. This is secured by the position of its center on the line of centers of the bearing balls.

There are a number of methods of retaining separator balls in position. Thus, in the double ball bearing, Fig. 10, there is a small tube in which the separator lies. This tube is funnel-shaped at each end. These funnels serve to compel the centering of the tube with the bearing balls. That is, when the bearing balls press against the two funnels, the axis of the tube is made to coincide with their line of centers, and this brings the center of the loosely held separator ball into its proper position.

In Fig. 10 is shown a radial bearing of the Chapman type. The tube with a funnel at each end may be clearly seen. Within the tube lies the separator ball, whose office it is to harmonize the contrary motions of the adjacent bearing balls. Of course, the adjustments of size in respect to the tube-funnel arrangement and the separator ball are such that when the bearing balls tend to crowd each other and so press upon the separator balls, the contact with the funnels is either slight or nothing at all. It is necessary, however, that the funnel and the bearing ball actually touch or approach each other fairly closely, as otherwise the centering of the tube with the line of centers of the bearing balls could not be counted upon to take place.

Ostrich Farming in Australia.

The first attempt to raise ostriches in Australia was made by a Mr. Malcom, who in 1880 brought 100 young birds from South Africa to South Australia. In the following year the parliament of South Australia enacted a law which granted to the first person who should exhibit 250 ostriches, more than one year old, about 2,400 acres of land suitable for ostrich farming. The conditions were satisfied by the South Australian Ostrich Company, which was founded in 1886, with a capital of $75,000. The company received land near Port Augusta on Spencer Bay, but in spite of this assistance the company has never paid a dividend, although it now possesses 1,100 ostriches, all of which were imported from South Africa. There is a still larger ostrich farm on the shore of Lake Albert, and smaller farms are scattered through the colony.

In New South Wales, ostrich farming was first attempted in 1897, by Barracluff, who imported six pairs of ostriches from northern Africa, and now possesses 84 birds.

Queensland and Victoria possess only small ostrich farms, which have not produced very encouraging results. In all, there are now about 2,000 ostriches in Australia. The inferior feathers are used at home, and the more valuable ones are exported chiefly to Germany.

A CURIOUS STAR MAP.

It would be more respectful to call this invention an "astronomical umbrella," but so many terms of humorous turn have been applied to the umbrella since the days of Jonas Hanway that it would be difficult for anybody except a boy scout to take this invention quite seriously.

The inventor, Mr. McEwan, is a Scotchman, and he has designed this apparatus for the study of the stars. The constellations and the Milky Way are all in their places, "ship-shape and Bristol fashion."

Just why an umbrella should have been used for this astronomical purpose surpasses our comprehension. In broad daylight such a chart would be obviously useless, and at night time nearly useless because of the difficulty of seeing the map at all.

Utility of Beekeeping.

Beekeeping is a valuable aid in the cultivation of fruit and seed crops. Insects which feed on nectar play an important part in the fertilization of flowers. Fertilization is effected in other ways, but the agency of insects is the more certain and efficacious, and no other insect is comparable with the honey bee in this respect. A strong hive contains 10,000 bees in February, 15,000 in March, 40,000 in April, and from 60,000 to 80,000 in May. It has been discovered by skillful observers that the average load of nectar carried to the hive by a bee is about 3/10 of a grain, so that the collection of one pound of nectar requires nearly 23,000 foraging excursions. By means of hives set on balances it has been found that the daily increase of weight in May averages 3.3 pounds. Occasionally, more than 11 pounds is gained in one day; and when the amount consumed by the bees and the loss of weight by evaporation are considered, it appears probable that the average daily quantity of nectar collected is not less than 11 pounds, which would load 250,000 bees. As a bee visits 10 flowers on the average in collecting a single load, some 2,500,000 flowers are visited in one day by the bees of a single hive. An additional large number of visits is required for the collection of pollen. These figures explain why many trees and plants bear small crops in the absence of bees.

The bee is charged with various imaginary crimes. Its sting is formidable, but chiefly to the imprudent. It is accused of ravaging fruit, but its tongue is formed exclusively for the extraction of sweet juices, and its mandibles are unable to pierce the skin of a fruit. Grapes have been taken intact from the interior of a hive in which they had been allowed to remain four days. A grape which had been smeared with honey was licked clean, but was not injured. The bees inserted their tongues in pinholes made in the skin of a grape, and extracted some of the juice, but they were unable to enlarge the holes. In some districts bees are menaced by insecticides intended for other insects. At Terricio, Italy, in 1907 all the bees were killed by spraying the olive trees with sodium arseniate mixed with molasses, for the purpose of destroying the olive fly.—Cosmos.