UNIVERSITY LECTURES.

ASTRONOMY.

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LECTURE II.

Ellipticity of the Earth.—Measurement of Meridional Arcs.—Figure of the earth Changed by Rotation.—Influence of the Centrifugal Fo ce on the Weight of Bodies.—Influence of Distance from the Centre on Weight.—Intensity of Gravity in different Latitudes determined by Pendulum Experiments.—Consequences of Increased or Diminished Rotation.—Causes of the Trade Winds.—Weight of the Whole Earth.—How Ascertained.—Density of the Earth.—Density of the Interior Compared with the Surface.

In our former lecture many evidences were examined which demonstrate the rotatory movement of our globe. Its diurnal rotation may also be proved to exist from a careful consideration of its true figure. When we loosely speak of its figure, we represent it to be a sphere—a globe, because it so nearly approximates to such a figure: and it is only by the most careful observations and measurements that we find any deviation from a sphere. Indeed, before the days of Newton, the earth was generally supposed to be a perfect sphere. But that great philosopher demonstrated that a globe composed in part of fluid materials, could not have a rotation upon an axis without changing its figure, by having its polar diameter shortened and its equatorial diameter increased. His calculation showed that the earth, if it rotate, must be flattened in its polar regions in the shape of a turnip, or an orange. Subsequent observations have verified his calculations and theory to be true; and the earth is no longer, in strictness, considered a globe, but an oblate ellipsoid or spheroid, having the diameter which coincides with the axis 1-300 shorter than the equatorial diameter.

It will be seen that the oblateness is so small that it does not differ much from a sphere. If we held in our hand a wooden model of our globe, whose diameter at the equator was 15 inches, the Polar diameter would lack only 1-20 of an inch of being the same length—a quantity so small that it could not possibly be detected by the eye, but would require very nice, delicate measurements to show its deviation from a globe.

For the purpose of determining the ellipticity of the earth, commissioners of various nations have been appointed by their respective governments, and furnished with the best of instruments to measure arcs of the meridian in different latitudes in various parts of the earth. By a comparison of all these measurements, it is found that the length of a degree increases with the latitude, being the least at the equator and the greatest at the poles; therefore, the curvature of the earth's surface must be greatest at the equator, and must decrease with the latitude, and be least at the poles. These meridional sections which pass through the poles, cutting the equator at right angles, are ellipses; and the geometrical properties of an ellipse are such that we are enabled to assign the proportion between the lengths of its major and minor axes, corresponding to any proposed rate of variation in its curvature; and having determined the proportion of the two axes or diameters, we can still further determine their absolute lengths by knowing the length of a degree in any given latitude. Mr. Airy, by a combination of 13 different arcs, measured in different parts of the earth, has determined its ellipticity and given the diameters as follows:

	Miles.
Equatorial diameter - - -	7925.648
Polar Diameter - - - -	7899.170
Polar compressions - - -	26.478

Proportion of diameter as 299.33 to 298.33.

Mr. Bessel has more recently calculated the same from a combination of ten of the measured arcs, and his results do not differ from the diameters as given by Mr. Airy the 1-16 part of a mile.

From a comparison of the above diameters, it will be seen that the equatorial regions of our earth are about 13 miles higher or more distant from its centre than the polar. This ascent from the two poles towards the equator is not sudden, but gradual, the elevation increasing at an average rate of about one mile in every 6 deg. 48 minutes, of difference of latitude, or 1 mile in 470. In traveling from the equator to the poles, there would be a rapid descent of 11 feet per mile. The Gulf of Mexico, at the mouth of the Mississippi river, is 4840 feet higher than Salt Lake City; and the Atlantic and Pacific oceans at the equator are elevated more than 5 miles above our city, and more than 3¾ miles above the highest peaks of the mountains which bound our valley on the east. The mouth of the Mississippi river is more than 1 mile higher than the city of St. Louis, which is situated upon its banks some 700 miles to the north. Its mouth is also several miles higher than the tops of the higest mountains from which it takes its rise. The equatorial ocean is 13 miles higher than the Arctic and Antarctic oceans. All these are phenomena arising from the spheroidal form of the globe.

When we speak of different mountains and places being elevated above the sea level, we have no reference to their relative elevations above the centre of the earth, unless when compared with that portion of the sea which has the same latitude as the places themselves. When we say our city is elevated 4300 feet above the sea level, we do not mean that it is so much higher above the centre of the earth than the equatorial or polar seas, but we mean that it is so much higher, or more distant from the centre of the earth than that portion of the sea which is in 40 deg. 45 minutes of N. latitude. That protuberant mass of land and water which envelopes our spheroid at the equator is more than 2½ times higher above the poles than the highest mountains upon the earth are above the sea level.

Perhaps some of this audience may be startled at these declarations and ready to call them in question as being contrary to their experience. How, it may be enquired, can water run up hill? Or how can the great ocean be prevented from rushing down from the equator to the poles? If there is an average of 11 feet fall per mile, how can water be kept from descending such a declivity? We answer, that it is the diurnal rotation of the earth upon its axis that preserves the earth in its present form, and that maintains the waters in their present state of equilibrium, and that causes the water of the Mississippi to run up an acclivity on its ascending jonrney towards the equator. Were it not for the rotation of the earth, the great protuberant mass of the waters would rush down from the torrid zone with awful and tremendous force, inundating the highest mountains in the temperate and frigid zones; the foundations of the great deep for hundreds of miles each side of the equator would be laid bare, and a zone of dry land would appear encircling the whole earth from east to west, connecting the equatorial portions of the eastern and western continents — while their northern and southern portions would be overwhelmed in the midst of two great polar seas. The surface of these polar seas would no longer maintain their elliptical form, but would take the form of a sphere; every part being equally distant from the centre of the earth.

The equatorial continent thus formed, would in the lapse of ages be worn down by the constant action of the seas, rains, &c.; and the worn off fragments and particles would eventually be scattered over the bed of the oceans in the form of pebbles, sand and mud, which would, like the fluid portions of the earth, seek their own level in the deepest portions of the polar seas; and in this manner the flattened portions of the solid spheroid would become rounded, and the whole earth, both solids and fluids, would assume the spherical form; and thus, in the course of millions of ages, under the present laws, if no rotation existed, the solid portions of our spheroid would become covered with a spherical ocean of uniform depth. Geological facts are said to afford abundance of evidence that the existing continents and islands have all undergone changes as great as the one which we have just described; they appear to have been, more than once, torn into fragments, reduced to powder, submerged in the great deep, and then by some process re-constructed and made new.

Let us next consider the case of a perfect globe of the magnitude of our earth, covered with an ocean of water of uniform depth, composed of materials of uniform density or, at least, of a density increasing at a uniform rate from the surface to the centre. All the particles of such a globe, if at rest. would be in a state of equilibrium. Now let such a globe begin by degrees to rotate upon an axis; let the rotation be accelerated until it shall perform one revolution in 23h. 56m. 4s.; it will then have a velocity equal to the earth. When this rotation commences, each particle, situated without the axis, would have a centrifugal force, or a tendency to recede from the axis, varying in proportion to its distance from it.

Near the poles where the centrifugal force at the surface of the globe is the weakest, it acts at nearly right angles to the force of gravity; the watery fluid under the influences of these two forces would be urged towards the equator; as the water proceeded upon its journey, its distance from the axis of motion would be increased and its centrifugal force would consequently be more powerful, though it would act at a disadvantage in consequence of its being more in opposition to the central force, that is, forming a greater angle with it than when near the poles; but still the direction of the resultant motion would be towards the equator. The obtuseness of the angle under which these two forces operate would continue to increase from the pole to the equator, at which place the centrifugal force would act in direct opposition to that of gravity, and consequently the particles would have no more tendency to proceed either to the north or south; but the whole effect of the centrifugal force *now* would be to render all bodies specifically lighter by their upward tendency from the centre.

Under these circumstances it is easy to perceive that the globular form of the ocean would not any longer be the form of equilibrium, and that the ocean surrounding the two poles must, in obedience to the laws of motion, proceed towards the equator and there form a protuberance of a sufficient elevation to counteract any further motion of the fluid particles, arising from the centrifugal force of rotation. The form thus assumed by the fluid ocean would be an oblate spheroid, which would be a permanent form of equilibrium as long as the rotation continued uniform. And it is also easy to conceive that the solid nucleus of the earth for thousands of miles around each pole would be laid bare, forming two great polar continents, while the ocean would encircle the whole earth, forming a belt or zone several thousand miles in breadth, of which the equator would be in the midst.

These polar continents, as we observed concerning the equatorial continent, would in the lapse of many ages become worn down and reduced to pebbles, sand, mud, &c., and be submerged beneath the ocean where, under the same laws of force and motion which govern the fluid elements, it would be carried towards the equator and arrange itself in a spheroidal form similar to that of the ocean with which it would be enveloped. Thus the whole earth would be covered with an ocean of nearly uniform depth, and both the solid and fluid portions would be in equilibrium, having a degree of oblateness sufficient to balance the combined effects of the centripetal and centrifugal forces. If by any means the rotation should be increased, the oblateness would be increased; the fluids upon the surface would first yield to the impulse and afterwards the solids would, by a slower process, arrange themselves in the form of equilibrium accomodated to the increased degree of rotation. Should the rotation be decreased down to its former velocity, an equatorial ridge of mountains would be formed. Should an increased or decreased rotation take place before the solids had time fully to arrange themselves in the form of equilibrum, theconsequence would be, that ridges or continents would be formed in different latitudes which in places that were of a softer texture might be worn down and submerged beneath the sea, while those of a harder and more unyielding nature might still be standing above the surface of the water in the form of continents and islands. We do not pretend to state that this is the way that the continents and islands of our earth have received their present form and position; but we merely state that such would be the natural tendency, were the earth to receive an addition or diminution to its velocity of rotation before the solid nucleus had time to fully accommodate itself to the different forms of equilibrium, corresponding to its different states of velocity. Whether the velocity of rotation has ever been greater or less than at the present time, we have not as yet discovered any means of ascertaining.

The fact that dry land and mountains do exist near the equator, elevated several thousand feet above the sea, would seem to indicate that the velocity of rotation has, at some former period, been greater than at present; otherwise there must have been some sudden convulsion sufficiently great to upheave from the bosom of the great deep the solid portions of the earth to the present elevations in those regions. Observation shows that there has been no perceptible change in the period of the earth's rotation during the last 2,000 years. If our earth were a globe when the rotation was first impressed upon it, its period must have been shorter, or its velocity greater than it would be after having assumed the spheroidal form, for the ocean receding from the poles where the centrifugal force is the least, and proceeding to the equator, where that force is the greatest, would, during its progress, be constantly accelerated in an eastern direction by virtue of its increased distance from the axis of rotation; the acceleration at first would not be sufficiently great to keep up with the velocity of the spherical mass over which it was passing; consequently it would lag behind, producing a rapid current towards the west, which, combined with the current proceeding towards the equator, would in the northern hemisphere incline it to the southwest, and in the southern hemisphere towards the northwest. These currents acting upon the spherical form of the earth over which they passed in a direction from east to west contrary to that of rotations, would have a tendency to retard that rotation. The momentum gained by the protuberant mass brought from the poles, would be exactly equal to the momentum lost by the whole sphere. Mathematicians, by knowing the proportions of the masses and velocities, could easily calculate the original velocity and period of the earth's rotation as a globe, from its present velocity and period as a spheroid.

Among the numerous phenomena resulting from the rotation of the earth may be mentioned the diminution of the weight of all bodies in proportion to the amount and direction of the centrifugal force with which they are affected. At the equator the decrease of weight is the greatest, amounting to 1-289 of its whole gravity.

The exact amount of the centrifugal force can be calculated if we know the dimensions of the earth and the time of its rotation. For instance, at the equator all bodies on the surface of the earth describe an arc of about 1,528 feet in one second of time; this arc deviates from a straight line or from the tangent about ⅓ of an inch; and a body will fall during one second about 193 inches. During the time that a body would fall, by its weight, 193 inches, it would have an upward tendency of ⅓ of an inch caused by the centrifugal force. This ⅓ of an inch, is nearly 1-289 of the whole distance through which a body would fall in one second if the earth were at rest. Hence a body would fall in one second 193 inches if there were no rotation, and 192⅔ inches with its present rotation; the downward tendency being diminished ⅓ of an inch by the tendency to recede from the centre in the direction of the tangent. Hence, also, bodies that weigh 288 lbs. at the equator, would weigh, at the same place 289 lbs. if the rotation did not exist, and the earth were maintained in its present shape. As you recede from the equator towards the poles, the centrifugal force diminishes and the weight of bodies increases. The rate of increase being as the square of the sine of the latitude; for instance, if we were to purchase at the equator 455 lbs of gold dust or any other substance; and bring it to the latitude of our city, it would weigh 456 lbs., increasing one pound by the increase of gravity; 194 lbs. at the equator, if transported to the poles. would weigh 195 lbs. Thus it will be seen that the fraction 1-194 expresses the excess of polar gravity over the equatorial.

There are two causes for the increase of gravity in going from the equator to the poles; one is the diminution of the centrifugal force, and the other is the elliptical form of the earth. This form alone, independent of the centrifugal force, would, at the poles, increase the weight of bodies 1-590 part; this added to 1-289, the fraction expressing the increase of weight when the centrifugal force is reduced to nothing, becomes equal to 1-194; that is 194 lbs. at the equator, if transported to the poles, would, in consequence of its removal from the influence of the centrifugal force, receive an addition to its weight amounting to a trifle over ⅔ of a pound; it would also receive another addition to its weight, arising from the elliptical figure of the earth, amounting to a trifle less than ⅓ of a pound; from both of these causes it would weigh just one lb. more than at the equator.

The variation of that force called weight or gravity, in different latitudes, may be very accurately determined by ascertaining the velocity with which a body falls in a given time, one second. One of the best methods of ascertaining the velocity is furnished us by the principles of mechanics. It has been mathematically proved from mathematical principles, that if one and the same pendulum be made to oscillate in different parts of the earth, that the squares of the number of oscillations in equal times at different stations will be to each other as the intensities of the force of gravity at these stations. For instance if at the equator, a pendulum of a certain form and length, make 86,400 oscillations in 24 mean solar hours, and when transported to Salt Lake City, it is found that the same pendulum makes 86,495 oscillations in the same time; then we know that the intensity of gravity at the equator is to the intensity of gravity at this city as the square of 86,400 is to the square of 86,495; or as 1 to 1.0022; or in other words, a mass of matter weighing 10,000 lbs at the equator will weigh at this place 10,022 lbs.

Great numbers of experiments of this kind have been made with the greatest possible accuracy in all accessible latitudes; and by these means the law of the variation of gravity in different latitudes has been developed, by which we are enabled to calculate, without any further observation, the difference of the weight of bodies in different latitudes; and by knowing the difference of the intensities of this force at different latitudes, we can calculate the true figure of the earth, and the degree of its oblateness without measuring an arc of the meridian. Who could have supposed that by the simple oscillations of a clock pendulum, mathematicians could sit in their chairs, and determine the proportions between the equatorial and polar diameters of our earth? But this is only one among ten thousand wonders opened to us by the skillful application of that grand key called *Mathematics*. It is highly satisfactory to know that the shape of our earth as ascertained by pendulum experiments, agrees with the shape deduced from the measurements of arcs of the meridian. And thus from two entirely different processes we arrive at the same great conclusion; and having thus demonstrated that the earth is an oblate spheroid, we know that it *must* have a rotation upon its axis in order to preserve the spheroidal form, so far, at least, as the fluid portions of its surface are concerned.

This may be illustrated by a very simple experiment within the reach of any one to perform. If a pail, partially filled with water, be suspended by a long string, and made to revolve swiftly around, the water within will be seen to arise around the sides of the pail, while the centre will be proportionately depressed; the greater the revolution the greater will be the depression of the centre, and the higher will the water arise around the interior sides of the pail; here then, in this simple illustration, we can see how water can be made to run up hill from the centre of the pail; and when it has once ascended, how its surface may be maintained in the form of a steep declivity by the continued rotation. As the water around the sides of the pail is maintainey at a greater elevation than at the centre or axis of the rotation, so is the water at thd equator maintained at an elevation or thirteen miles above the water at the poles