MOTION IN CURVED PATH

(According to '*Hypothesis on* MATTER')

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Abstract: All natural (inertial) motions are in straight lines. Rotating motion or motion of a macro body in curved path is the result of simultaneous straight-line motions of its 3D matter particles in different directions at differing linear speeds, appropriate to their locations in the macro body. A macro body, moving in a circular path, is under a constant inward effort (central force). It simultaneously has linear motions in two directions. Direction of one of the linear motions is towards the centre of circular path, in the direction of 'centripetal force'. Direction of other linear motion is deflected outward from the tangent to circular path. Outward component of this linear motion gives rise to the assumption of imaginary 'centrifugal force'. In cases of motion in a circular path, centripetal motion of a macro body not only compensates outward component of its linear motion but also deflects direction of its linear motion inward by a constant magnitude. Explanations on rotary motion with respect to absolute (inertial) reference frame can give real parameters without the use of imaginary entities.

Work, invested about a macro body by an external effort, continues to act on the body even after cessation of external effort, until work about the macro body is stabilized and the body attains a steady state (of motion). Phenomenon of inertial delay operates not only during application of an external effort but also during its cessation. Ignoring this fact caused the assumption that the direction of instantaneous linear motion of a macro body, moving in a circular path, is tangential to its path.

Keywords: Effort, Force, Work, Inertia, Motion, Centrifugal force, Centripetal force, Bucket argument, Momentum, Galactic radius, Gyroscopic inertia, Precession, Hypothesis on MATTER.

Introduction:

'Hypothesis on MATTER' describes an alternative concept. In it: Whole matter in nature is in the form of 'quanta of matter', which fill entire universe. Matter content of a body and energy about it are distinctly separate. They cause and support each other for their existence and stability. They are not convertible into each other. Matter content of a macro body is the sum of three-dimensional matter in it. Energy is the stress, developed due to 'distortions', in the natural latticework arrangements of quanta of matter in and about a 3D matter body. '2D energy fields', two-dimensional latticework structures formed by single-dimensional quanta of matter, fill the entire space. 2D energy fields, in various directions and planes, passing through a point, co-exist. 2D energy fields, made up of quanta of matter, have all properties of an ideal fluid. Parts of 2D energy fields, within spatial dimensions of a macro body, contain sufficient distortions to sustain integrity and stability of the (macro) body in its current state. This part of 2D energy fields is the macro body's 'matter field'. Additional distortions in a matter field are 'additional work', existing about the macro body and it determines state of (motion of) the macro body. All apparent interactions between 3D matter particles take place through the 'universal medium' of 2D energy fields. This avoids the assumption of 'actions at a distance through empty space'.

'2D energy fields' is aether-like universal medium with definite constituents, structure and properties. Displacement of distortions in 2D energy fields transfers work about a macro body. Stress, produced by distortions (work) in 2D energy fields is energy, associated with the macro body. Because of compressibility of 2D energy fields, due to their latticework structure, transfer of additional work is subject to time delay. Transfer of additional work, once stabilised, will continue at a constant speed until modified by further additions. This phenomenon ensures a matter body's steady state (of motion) in space. An action, subjected to time delay (during stabilisation) and maintains steady state (after stabilisation), is an inertial action. The adjective 'inertial' is used in this article to qualify an action that invokes the phenomenon of inertia rather than to indicate 'fictitious' nature of an apparent action. Mathematical relation, the rate of transfer of additional work (distortions in matter field), is 'force' (or 'power'). All efforts (natural forces) originate from gravitational actions by 2D energy fields, on 3D matter particles within them.

It is an inherent property of 2D energy fields to strive towards isotropic and homogeneous state. Distortions in any part of 2D energy fields tend to spread-out. They are transferred from higher distortion-density region to lower distortion-density region. During transfer of distortions, any 3D matter particles in that region of 2D energy field are also carried along with the distortions. Transfer of 3D matter particles in a macro body causes macro body's motion in space. 3D matter is incapable of any actions or movements on its own. It is the inertial actions of 2D energy fields, about a 3D matter body, which move it. Therefore, property of inertia (currently attributed to matter bodies) is an inherent property of 2D energy fields (universal medium), in and about a macro body (its matter field). Inertial delay is required for changes in matter field-distortions to spread-out evenly within the matter field that receives or loses additional work.

All conclusions expressed in this article are from the "*Hypothesis on* MATTER" [1]. For details, kindly refer to the same. Figures are not to scale. They are used only to depict actions described. A curved path is the sum of parts of numerous circular paths. Each part of the curved path may have different centre of curvature or it may be part of a circular path. Hence, in this article, we shall consider motion in a circular path to represent a macro body's motion in curved paths. A macro body is constituted by more than one basic 3D matter particle. A free body is that exists in a region of universal medium, outside influences except gravitational effects from other macro bodies.

Mechanism of motion:

All actions are recognized by motion or deformation of 3D macro bodies. Motion is displacement of 3D matter bodies in space. Deformation is displacements of parts of a 3D macro body with respect to other parts of the same macro body. True actions (linear motion, rotational motion, etc.) can be understood only with respect to an absolute reference. Universal medium (2D energy fields), envisaged in 'Hypothesis on MATTER' is reasonably isotropic, homogeneous, static and extends infinitely to provide an absolute reference. All actions, related to motion of a 3D matter body, are carried out by the universal medium (2D energy fields) about the 3D matter body. 2D energy fields are in direct contact with every 3D matter particle in the universe. All motions and their mechanism of action are associated with phenomenon of 'inertia'. For details on mechanism of motion, please see article on 'Inertia' [3].

2D energy fields are latticework structures formed by quanta of matter. They fill the entire space. All possible planes in space have one 2D energy field, each. Together they form an all-encompassing universal medium. 2D energy fields are reasonably stable and homogeneous. They are self-stabilizing matter bodies. Displacements of quanta of matter in 2D energy field, with respect to each other create distortion in a 2D energy field. Distortions in 2D energy fields, about a 3D matter body are work done about the matter body. Intrinsic work about a macro body forms and sustains integrity and physical state of the macro body and all its constituent 3D matter particles. Region in 2D energy fields, in and about a 3D macro body, where 2D energy field-distortions (work) about the macro body are situated is the macro body's 'matter field'. Action of an external effort on a macro body is to introduce additional distortions (work) into its matter field. Mathematical relation between additional work, introduced into matter field of a 3D macro body, and mass of the 3D macro body (representing its matter content) is the 'force'.

State of motion of a 3D macro body is determined by magnitude of additional work (more than those required to maintain integrity of the macro body and its constituent 3D matter particles) associated with it. Time interval, required for the distribution and stabilization of additional distortions (work) in a matter field, is the inertial delay. Inertial delay is the time interval between the instant of commencement (or cessation) of action by an external effort on a 3D macro body and the instant at which all of its 3D matter particles have completed their response to the action of the external effort, by which time the macro body has attained a steady state of motion. Due to inertial delay, a 3D macro body takes certain time interval after commencement of an action by an external effort to stabilize its speed and reach a steady state of motion. Similarly, it takes certain time interval for a 3D macro body after termination of action of an external effort to stabilize its speed and reach a steady state of motion. Unfortunately, the second part mentioned, is usually ignored. Length of inertial delay depends on the size of the 3D macro body in the direction of external effort and its 3D matter density [3]. Larger 3D macro bodies and 3D macro bodies of lower 3D matter-density take longer to reach steady states (of motion). After their stabilization, matter field-distortions continue to be transferred through the 2D energy fields at a steady speed. Transfer of matter field-distortions in 2D energy fields moves constituent 3D matter particles of the 3D macro body. Additional distortions in a matter field, in each 2D energy field, travel in straight lines in their own planes. This makes the paths of natural motions of all 3D matter bodies in space, inherently in straight lines.

Motion of a 3D macro body, in space, is with respect to an external reference. Reference could be a point in the (generally) stable and homogeneous 2D energy field or with respect to another 3D matter body in space. 2D energy fields substitute for absolute space, external to 3D matter particles. A relation with respect to 2D energy fields provides an absolute reference. All parameters of a 3D macro body, obtained with respect to an absolute reference are true. When another 3D macro body in space provides the reference, we have relative motion. When relative motion is used, motion of the reference body, depending on their relative directions of motion, is added to or subtracted from the motion of referred 3D macro body. Results obtained are apparent parameters of the 3D macro body or its path, with respect to static reference body.

Motion of a 3D macro body, in curved path, is combination of numerous straight-line motions. Action of an external effort on a 3D macro body is to change magnitude and/or direction of its motion or curve its path of motion. External effort, curving the path, acts at an angle to the straight line of (inertial) motion of the 3D macro body. For motion in a circular path, external effort acting on a 3D macro body has to be of constant magnitude and perpendicular to 3D macro body's (instantaneous) average straight-line path. In the following explanation, motion of a 3D macro body in circular path is described. Principle of motion in any curved path is similar to motion in circular path, with small differences in relative direction and duration of application or changes in the magnitude of external effort.

Resultant of two motions:

Magnitude of total distortions in the matter field of a macro body is the magnitude of work associated with the macro body. Parts of total work, required for creation of macro body's constituent matter particles, their development into a combined body and for the integrity and stability of the macro body is the magnitude of intrinsic work associated with the macro body. Remaining 'additional distortions', contained in macro body's matter field determine macro body's state of motion. Due to latticework structure of 2D energy fields, distortions in them (except those produced by gravitation) cannot remain stationary at any location. Additional distortions in a macro body's matter field are transferred through 2D energy fields, in the direction of their introduction. 3D matter particles of the macro body, which happen to be in the path of moving-distortions, are also carried along with them. Displacement of constituent 3D matter particles, move the macro body as a whole.

Action of an external effort on a macro body is to introduce additional distortions into its matter field. Magnitude of additional distortions in the matter field of a macro body is the magnitude of additional work done about that macro body, as a whole. Newly introduced additional distortions in the matter field;

(1) If they are in the same direction as the additional distortions, already present and maintaining inertial motion of the macro body, they will add together to accelerate the macro body and enhance its speed.

(2) If they are in opposite direction to the additional distortions, already present and maintaining inertial motion of the macro body, they will subtract from each other to decelerate the macro body and reduce its speed.

(3) If they are in any other direction, they will accelerate the macro body in their direction and deflect macro body's direction of motion.

Additional distortions in a macro body's matter field travel only in straight lines and thus directing steady state motions of all its constituent 3D matter particles in straight lines. As long as magnitude (and direction) of additional distortions (additional work) in the matter field of a macro body remain constant, the macro body will continue to move at a constant speed (in a straight line). A change in the magnitude (or direction) of additional distortions produce instability in the macro body's state of motion. It will take certain time for the changed additional distortions to stabilize. This is the accelerating/decelerating period of the macro body.

If an external effort acts on a linearly moving macro body, in a direction deflected from its line of motion, it will introduce additional distortions into macro body's matter field in its own direction. These will form another set of additional distortions in addition to original additional distortions, which are already moving the macro body at constant linear speed. Additional displacement of constituent 3D matter particles of the macro body deflects whole macro body from its original direction of motion. As the macro body is deflected away from the direction of its original constant linear motion, 3D matter particles of part of the macro body moves away from the path of moving distortions in its matter field. Irrespective of displacement of constituent 3D matter particles of the macro body, travelling distortions in the macro body's matter field continue to be transferred in the same direction and they are lost from the macro body's matter field into 2D energy fields outside the macro body's matter field. Total additional work in the direction of macro body's original linear motion is reduced.

In the mean time, due to its linear motion, the macro body is also moving away from the direction of additional distortions due to external effort. If the action of external effort is only for a limited time, the macro body will be gradually carried away from the influence of additional distortions due to external effort and these additional distortions will escape into (space) 2D energy fields, outside the macro body. If the external effort on the macro body is maintained continuously, as in the case of motion in a circular path, introduction of additional distortions into macro body's matter field will continue at a constant rate, same as the rate of additional distortions lost from the macro body's matter field. Due to constant renewal of additional distortions by the external effort, the macro body will accelerate continuously at a constant rate. At the same time, as the magnitude of newly introduced additional distortions and the additional distortions lost from the matter field are equal, total magnitude of additional distortions in macro body's matter field remain constant in magnitude. A constant magnitude of additional distortion in a macro body's matter field drives the macro body at a constant speed. Due to this fact, even though the macro body (moving in a circular path) is accelerating continuously at a constant rate, its (radial) speed remains constant.

During macro body's displacement towards the centre of curvature of its path, certain part of additional work (producing its motion in straight-line path) is lost from its matter field and certain part of additional work (producing its motion towards the centre of curvature) is stored within its matter field. These additional distortions together form resultant additional distortions in the matter field, to produce macro body's motion in resultant direction of both motions. Instantaneous changes in the resultant direction of macro body's motion cause the curvature of its path.

Since direction of macro body's motion changes continuously, additional distortions due to original inertial motion and due to action of external effort (which are transferred in corresponding straight-line directions) are continuously modified. Current additional distortions in the macro body's matter field, at any instant, are compatible for present motion of constituent matter particles of the macro body. Their magnitude and direction depends on the magnitude of resultant linear (instantaneous) speed of the body.

Centrifugal force:

We observe displacements of matter bodies in space with respect to references - another macro body or a point. Without a reference, motion of a macro body is not tangible. Best reference is a fixed point in space itself. This would provide an absolute reference frame for all action about a macro body. However, since the space has no structure, it cannot provide a reference point. All points in space are identical with respect to a moving macro body. As long as the space is considered formless, we may have no absolute reference or absolute motion.

Next best alternative for observation of a macro body's state of motion is a relative reference frame. In this, a matter body in space or a point on a macro body is assumed static, so that instantaneous locations of other macro bodies may be referred to this static body/point. Parameters of motion and location of the referred macro body with respect to the reference body/point can be accurately predicted. However, while considering observational relative reference frame, we are not definite about which of the bodies is moving. It could be either the referred macro body in one direction or the reference body in opposite direction. In either case, only relative parameters of motion will be correct. Observational relative reference frames cannot give true parameters of a macro body's motion, its location in space or shape of its path. Work-done, to change the state of a reference body's motion in one direction may appear to be equal to magnitudes of work-done to change states of motion of each of many referred bodies in opposite direction. This is not true.

Relative reference frames of observations, related to states of motion of macro bodies, may be generally classified into inertial and non-inertial reference frames. Newton's laws of motion are true in any reference frame that is moving at a constant velocity (inertial reference frame). In an inertial reference frame, at any instant, phenomenon of inertia compels a moving macro body (in its stable state) to travel in a straight line.

To move in a circular path, a linearly moving macro body requires the action of an external effort (called 'centripetal force') towards the centre of the curved path. Macro body accelerates towards centre of curvature of the path. It is believed that displacement of the macro body, along its straight-line path and the displacement due to the acceleration by the 'centripetal force' towards the centre of curvature, together, result in the body's circular path. It should be noted that at every instant the macro body is moving towards centre of its circular path under acceleration provided by 'centripetal force', taking the macro body nearer to centre of rotation. Considering this motion in inertial frame of reference, the macro body would logically move in a path spiralling towards centre of its curved path. Since this does not happen, the action cannot be considered in inertial frame of reference. In order to overcome this inconsistency, the situation is considered in rotational frame of reference (a non-inertial reference frame). Continuous radial acceleration of the macro body justifies this choice.

Observations, related to states of motion of macro bodies, do not appear to be true in accelerated (non-inertial) reference frames. Instead, in an accelerated reference frame, moving bodies appear to have external efforts, which are not in fact present, acting on them. These apparent efforts are called 'pseudo (or imaginary) forces'. Since rotational motion is always an accelerated motion, 'pseudo (imaginary) forces' are always associated with rotating frames of reference.

In order to balance efforts on the macro body in various directions and thereby reduce magnitude of total resultant effort acing on the macro body to nil value, an imaginary effort ('centrifugal force') is assumed to act on a macro body (moving in circular path) in the direction opposite to 'centripetal force'. The 'centrifugal force' is then assumed to accelerate the macro body by an equal magnitude as that is provided by the 'centripetal force', but in opposite direction. Neutralisation of acceleration due to 'centripetal force' prevents the macro body from spiralling towards the centre of its circular path. Having efforts in opposite directions (in perpendicular direction to its linear path), leaves the macro body to pursue its motion in circular path at a constant speed.

'Centrifugal force' is an assumed quantity (peculiar to a macro body moving on a circular path) that has the same magnitude and dimensions as the 'centripetal force' (which keeps the macro body on its circular path) but apparently acts in opposite direction. 'Centrifugal force' is invoked by an observer to maintain the validity of Isaac Newton's second law of motion in a rotating (or otherwise accelerating at a constant rate) reference frame. In an inertial reference frame, the 'centrifugal force' refers to a 'fictitious effort', which appears to act on the macro body (moving in circular path) and in a non-inertial reference frame; it refers to 'reaction' to 'centripetal force', by which the macro body (moving in circular path) influences other macro bodies. When used as a 'fictitious effort', it is useful in analyzing the motion of a macro body in a rotating reference frame.

'Centrifugal force' is an imaginary entity that appears in (non-inertial) rotational reference frames. All attributes of a real effort are assigned to it. Since Newton's first law of motion is not applicable in rotational reference frame, a body moving in circular path is assumed to maintain its circular path when resultant of a system of efforts on the macro body is nil. This is achieved when magnitude of 'centrifugal force' is equal to the magnitude of 'centripetal force' and they are in opposite directions. In a rotating reference frame, it is assumed that motion of a macro body under inertia (its steady state of motion) is along a circular path about the spin axis. 'Centrifugal force' appears only when there is a 'centripetal force' present in a system. Magnitude of action of 'centrifugal force' is equal to the magnitude of action of 'centripetal force' and it is in opposite direction.

Magnitude of imaginary 'centrifugal force', on a macro body moving in circular path, can be increased by increasing either (1) linear speed of the macro body, (2) mass of the macro body, or (3) radius of macro body's circular path (distance of the macro body from the centre of its curved path). None of these methods produce, augment or create real effort in the direction of 'centrifugal force'. Magnitude of imaginary centrifugal force on a macro body, moving in a circular path at (small) constant linear/angular speed is given by the relation;

$$F = mv^2 / R \,;$$

Where F is the magnitude of 'centrifugal force', m is the 'mass' of the macro body, R is the radius of circular path, v is the tangential (average) linear speed of the macro body.

'Centrifugal force' is usually expressed in terms of acceleration due to gravity.

Considering magnitude of 'centrifugal force' in terms of linear momentum of the body; 'mv' is the linear momentum of a macro body.

Splitting the equation for magnitude of 'centrifugal force'; $F = (mv)\,\omega$ **(1)**

where 'ω' is the angular speed of the (linearly moving) macro body, along its circular path.

Outward departure of macro body from tangent to circular path, $d = v \operatorname{Tan} \omega$ / unit time

For small values of 'ω', $\omega = \operatorname{Tan} \omega$

$$d = v \operatorname{Tan} \omega = v\,\omega$$

$$F = \frac{mv^2}{R} = mv\frac{v}{R} = mv\omega = md$$

Under the assumption that the macro body's linear speed is unaffected, its linear momentum remains constant. Magnitude of 'centrifugal force' on the macro body (moving along a circular path at constant linear speed) is equal to magnitude of 'centripetal force' (but in opposite direction) on the macro body. A change in the magnitude of 'centripetal force' by the help of external action is automatically reflected in the magnitude of 'centrifugal force' and in a corresponding change in the magnitude of angular speed of the macro body. Equation (1) remains valid only for values of angular speed of the macro body, where value of 'ω' is much less than π/2 per rotation.

A macro body, moving in a circular path is continuously changing the direction of its velocity and therefore, accelerates towards the centre of its circular path. External effort, required to produce this acceleration, is provided by the 'centripetal force'. If the macro body is moving at constant speed, provided by inertia, 'centripetal force' is the only external effort acting on the macro body. If the 'centripetal force' is terminated, the macro body (because of inertia) will appear to continue to move in a straight line, tangential to its previous circular path. Observation of this fact has led to the assumption (without any logical reason) that the direction of a macro body's instantaneous linear motion is always tangential to its circular path. This assumption is valid only in cases, where value of angle subtended by tangential displacement of macro body in unit time and trigonometric ratio of angular displacement of the macro body are approximately equal.

Length of a segment of a circle is assumed to be the product of angle subtended by it at the centre and length of circle's radius. Hence, instantaneous tangential linear speed of a macro body, moving in circular path, is assumed to be the product of angular speed (in radians) and the radius of the circular path. It may be noted that; however small a segment of a curve is, its length is different from the length of the tangent (enclosed by the angle subtended by the segment) at any point on the segment. For all practical purposes involving small macro bodies moving in curved paths of reasonably large radius, calculations based on these assumptions do not make observable differences. However, if the macro body involved is very large with reasonably large radius of curvature of its path or the macro body is very small with small radius of curvature of its path, considerable discrepancy will appear in the result.

Bucket argument revisited:

Isaac Newton's 'bucket argument' was designed to show that true rotational motion could be defined only with respect to absolute space (a static universal medium). It cannot be defined with respect to surrounding matter bodies, whatsoever states of motion they have. Even if the whole universe (surrounding a bucket of water on earth's surface) rotates about the bucket, water surface in the bucket will remain flat, unless the bucket itself has a true spin motion with respect to an absolute reference. Real spin motion of a bucket and water in it is bound to change shape of upper surface of the water body. Further mathematical analysis has pointed towards a real action by the imaginary 'centrifugal force'. It is not logical for imaginary efforts to cause real action. However, analysing actions of body-particles of the water body (in rotating bucket in universal medium) by work associated with them (instead of equilibrium of 'forces' on it) can give logical explanation of actions, without the use of imaginary 'centrifugal force'. Changes in the shape of water surface in the spinning bucket are produced by two independent actions. One of the actions is produced by work associated with motion of body-particles of water body in circular path in conjunction with work associated with gravitational attraction on body-particles towards earth. Other action is produced by the work associated with 'centripetal force' by the rigid bucket on the water body.

For the time being, we may neglect the container and use rotary motion of a fluid macro body for discussion. Intrinsic work about a matter body creates and develops constituent body-particles and sustains integrity and stability of the macro body. State of motion of a macro body depends on additional work associated it. Motions of body-particles may represent additional works, associated with each action on/about the water body. In this article, we may neglect intrinsic part of the total work associated with the macro body and consider only the additional work, which is responsible for the macro body's motions and deformations, as the sole work associated with the macro body. Since 'force' is the mathematical relation between work and displacement, in this article, work is represented by motion in direction and magnitude.

Direction of instantaneous motion of a body-particle (away from centre of rotation) of a rotating macro body is deflected away from the tangent to circular path (as explained below). If the rotating body is fluid (or solid of lower viscosity), inertial actions on the rotating macro body tend to spread its material content radially, in the plane of its rotation. Body-particles, attempting to move away from center point, are resisted by cohesive efforts ('centripetal forces') within the macro body. Magnitudes of radial motion of body-particles are proportional to their (derived) tangential speed. A fluid macro body has low rigidity and its body-particles are free, up to an extent permitted by viscosity of the fluid, to move in relation to neighboring body-particles. Body-particles nearer to point of action of an external effort, usually, move faster than body-particles away from the point of action of the external effort. Body-particles, at the point of action of external effort, are moved directly by the mechanism applying the effort and other nearby body-particles are pulled along with faster moving body-particles by adhesion between them. Hence, (derived) tangential speed of a body-particle in a rotating fluid macro body need not always be in proportion to its distance from the point of application of external effort.

If a fluid macro body (rotating in plane parallel to the surface - horizontal plane) is on/near the surface of a larger macro body, the rotating fluid macro body is under the influence of gravitational (apparent) attraction towards the larger macro body, in addition to inertial actions about it. Gravitational attraction on fluid macro body's body-particles tends to move them towards the larger macro body, in a direction perpendicular to their motion in circular paths. Now, each body-particle of the rotating fluid macro body is under two independent motions. They are;

(1) Angular motion in horizontal plane, about the centre of rotation. This may be resolved into two components;

a) Angular motion about the centre of rotation, tangential to curved path.

b) Linear outward motion, away from centre of rotation, in the plane of rotation. (We shall consider this component, when fluid macro body in a container is considered)

(2) Linear motion in vertical plane, towards the larger macro body.

If matter particles of the fluid macro body were free to move towards the larger macro body, magnitudes of displacement in vertical plane, produced by (apparent) gravitational attraction, would have been equal on all body-particles of the rotating fluid macro body. Hence, work invested about each body-particle in downward direction is equal in magnitude. This is because the magnitudes of acceleration due to gravitational attraction are equal on all of them. Magnitudes of work (rate of displacement) in horizontal plane, produced by rotational motion, are proportional to angular speeds of the body-particles. Resultant directions and magnitudes of work about body-particles depend on its angular speed. Greater angular speed of the body-particle reduces its rate of displacement towards the larger macro body, due to gravitational attraction. Lower angular speed of the body-particle increases its rate of displacement towards the larger macro body, due to gravitational attraction. If the fluid macro body is in a container, in static state, its body-particles cannot be displaced towards the larger macro body. However, in a spinning fluid macro body, changes in the magnitudes of work associated with body-particles (actions equivalent to the magnitudes of possible displacement) can make changes in their locations relative to each other. Relative positions of body-particles, situated along radial lines on the surface of the fluid macro body determine shape of upper body-surface of the spinning fluid macro body.

If the rotating effort (torque) is applied near the periphery of fluid macro body (like, liquid kept in a spinning container) placed on the surface of another larger macro body, body-particles nearer to its periphery have greater angular speed compared to body-particles nearer to its centre of rotation. Consequently, body-particles nearer to periphery of fluid macro body have lesser resultant additional work / displacement towards the larger macro body compared to resultant additional work / displacement of body-particles nearer to centre of rotation of fluid macro body. Difference in magnitudes of resultant additional work, shown by probable displacements corresponding to additional work, creates variation in compressive pressures experienced at different parts of the fluid macro body. The rotating fluid macro body has lower downward pressure nearer to its periphery and higher downward pressure, nearer to center of its rotation. In order to reach equilibrium state, fluid macro body's upper surface (away from the larger macro body) assumes concave shape. Surface of the fluid rotating macro body, nearer to periphery, rises above the original surface level and surface nearer to centre of rotation falls below the original surface level, as seen in whirlpools or as seen in Newton's bucket experiment.

Part A of figure 1 shows surface of a fluid macro body on/near the surface of a large macro body. 'a', 'd', 'g' and 'j' are few body-particles of the fluid macro body. Body-particle 'j' is near the outer periphery and others are evenly placed nearer to centre of rotation of the fluid macro body. Let an anti-clockwise torque, acting at its periphery, rotate the fluid macro body. Initially, outermost layer of the fluid macro body attains angular motion. As this layer is rotated, friction between subsequent layers tends to turn whole of the fluid macro body along with the outer layer. However, due to low viscosity of the fluid, fluid macro body picks up angular motion, gradually. First, the outer layer near the periphery starts to rotate and this rotary motion is transferred gradually to inner layers of the fluid macro body. At any instant, outermost layer has highest angular speed. Angular speeds of inner layers towards the centre of rotation gradually reduce. 'ab', 'de', 'gh' and 'jk', respectively show magnitudes of additional works associated with the body-particles, corresponding to their angular motions. Magnitudes of additional works associated with gravitational attractions on all body-particles are equal and they are represented by 'bc', 'ef', 'hi' and 'km'.

If the body-particles were free to move downwards, their resultant motions would have corresponded to resultant additional work associated with them, along lines 'jm', 'gi', 'df' and 'ac'. Considering body-particles along a radial line (at the centre of figure), magnitudes of resultant additional works associated with them (corresponding to probable displacements) in downward direction are shown by lines 'p', 'q', 'r' and 's'.

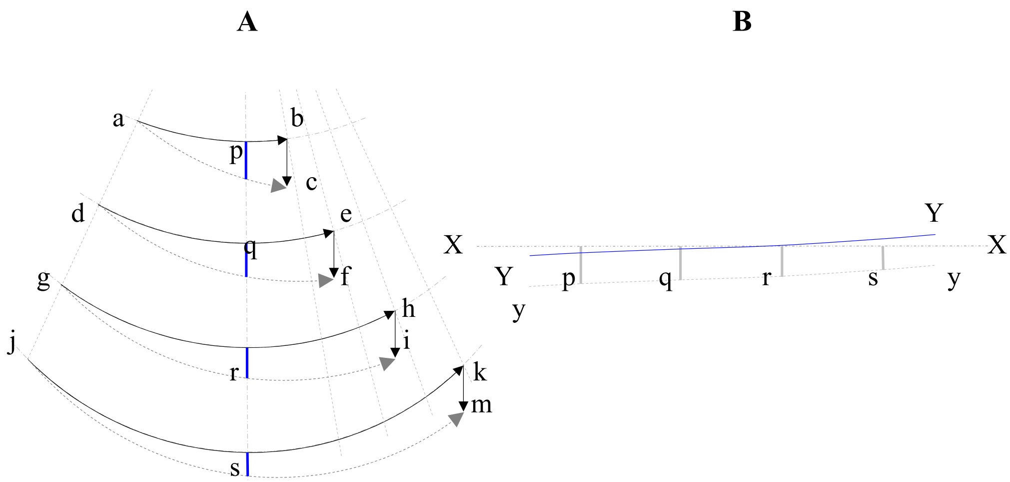

Figure 1

Magnitude of ‘p’ > magnitude of ‘q’ > magnitude of ‘r’ > magnitude of ‘s’.

Downward deflections of body-particles’ probable paths increase as their distances from centre of rotation reduce. Tendency for unequal vertical displacements of body-particles create internal pressure within the fluid macro body. To reach equilibrium, surface of the fluid macro body will assume appropriate curved shape. Body-particles nearer to centre of rotation have greater downward pressure on them. Body-particles farther from the centre of rotation have lesser downward pressure on them. Body-particles nearer to centre of rotation will depress by greater magnitude to raise body-particles nearer to outer periphery and form concave shape on the surface of the fluid macro body.

Part B of figure 1 shows part of the surface-cross section with its left-hand side towards the centre of rotation. XX is a radial line on the surface, when the fluid macro body is not spinning. ‘p’, ‘q’, ‘r’ and ‘s’ shows the probable depth to which its surface could be depressed due to rotary motion. Curved line ‘yy’ shows the probable surface, when the fluid macro body is spinning. Since the volume of fluid macro body cannot be reduced, surface of the macro body on one side of centre of rotation will reach a resultant level as shown by curved line, YY. Right-hand side of the figure is towards the periphery and left-hand side of the figure is towards the centre of rotation. Surface nearer to periphery will rise and surface nearer to centre of rotation will fall to create a concave surface.

If the fluid macro body is in a container, relative motion of the fluid macro body with respect to the container is bound to cause additional efforts on it. Let us consider water in a bucket situated on the surface of earth. When the bucket is in steady state of motion with respect to earth, surface of the water in the bucket may be considered as flat. Let us spin the bucket. As the bucket starts to spin, friction between the bucket and the water body initiates spin motion of water in it. Rotational speed of water body towards the centre of rotation diminishes gradually. Difference in angular speeds of body-particles in the water will cause surface of water to form concave shape as explained above.

In addition, as the fluid macro body is contained, free motion of its body-particles are restricted within the container. The container restricts outward motion of body-particles in horizontal plane. Container exerts an effort on the body-particles to neutralize their outward component of angular motion. This effort, ‘centripetal force’, is real and hence it can do additional work. Additional work, introduced by ‘centripetal force’ neutralizes certain part of additional work associated with the angular motion of body-particles in horizontal plane. Reduction in the outward additional work due to rotary motion by additional work due to ‘centripetal force’ not only compensates for removal of outward displacements of the body-particles but also displaces the body-particles inward, towards the centre of rotation, to maintain steady curvatures of their paths.

Rigid container restricts the periphery of the rotating fluid macro body. Outward moving tendency of body-particles tend to press on the container and thus increase compressive pressure in the fluid near container wall. Magnitude of compressive pressure is related to angular speed of body-particles. Body-

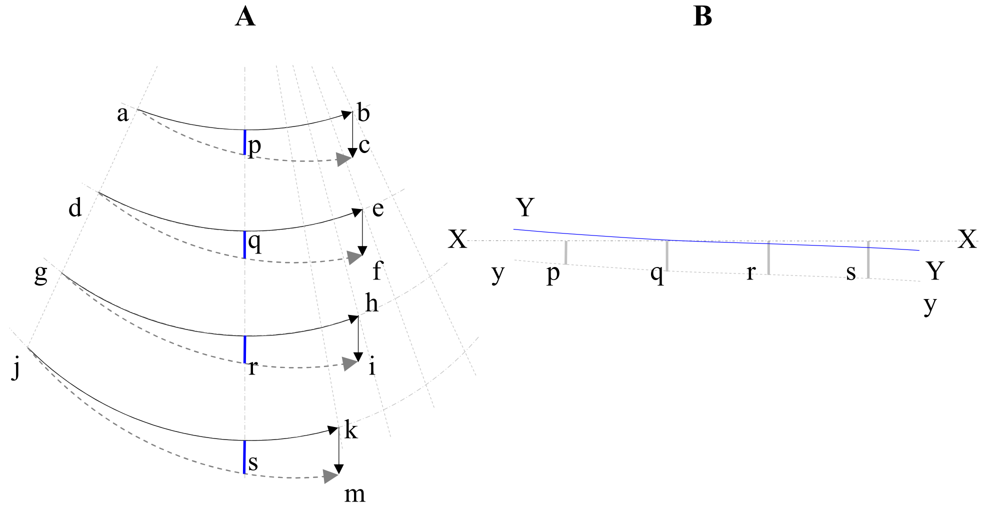

Figure 2

particles nearer to the periphery will experience greater compressive pressure and body particles nearer to the centre of rotation will experience lesser compressive pressure. In order to reach equilibrium state, fluid surface near and towards the container wall may rise and curve the surface of fluid to concave shape. This curvature is in addition to concave curvature formed by rotary motion of the fluid macro body. This action, in a non-inertial reference frame, refers to a 'reaction' to 'centripetal force', applied by the container, to restrict outward motion of body-particles of the fluid macro body.

From above explanations, it can be seen that concave shape of water surface, obtained during the 'bucket experiment' is due to differences in rotational speeds of body-particles and internal compression caused by 'centripetal force', provided by the rigid container. These are the real causes of changes in the shape of water surface in bucket experiments rather than assumed real actions by fictitious 'centrifugal force'.

If the rotating effort (torque) is applied near the centre of fluid macro body (like; fluid body is spun by an impeller at its centre) placed on the surface of another larger macro body, body-particles nearer to periphery of fluid macro body will have lower angular speed compared to body-particles nearer to its centre of rotation. Rotational speed of fluid macro body towards the periphery diminishes gradually. Consequently, body-particles nearer to periphery of fluid macro body have greater resultant additional work (probable displacement) towards the larger macro body compared to resultant additional work (probable displacement) of body-particles nearer to centre of rotation of fluid macro body. Difference in magnitudes of resultant additional works creates variation in compressive pressures experienced at different parts of the fluid macro body. Rotating fluid macro body has greater compressive pressure nearer to its periphery and lower compressive pressure, nearer to center of its rotation. In order to reach equilibrium state, fluid macro body's upper surface (away from the larger macro body) assumes convex shape. Surface of rotating fluid macro body nearer to its centre rises above the surface, nearer to periphery, as seen in cyclones. Tendency of central region to rise enhances any other lifting effort, present in the central part of the fluid macro body.

Part A of figure 2 shows surface of a fluid macro body in a container, on/near the surface of a large macro body. 'a', 'd', 'g' and 'j' are few body-particles of the fluid macro body. Body-particle 'j' is near the outer periphery and others are evenly placed nearer to centre of rotation of the macro body. Fluid macro body is being rotated in anti-clockwise direction by an impeller at its centre. As the impeller rotates, it tends to turn the fluid macro body also along with it. However, due to low viscosity of the fluid, it picks up angular motion, gradually. First, the layers near the centre start to rotate and this rotary motion is transferred gradually to outer layers of the fluid macro body. At any instant, inner most layer has highest angular speed. Angular speeds of outer layers towards the periphery gradually reduce. 'ab', 'de', 'gh' and 'jk', respectively show magnitudes of additional works associated with the body-particles, corresponding to their angular motions. Magnitudes of additional works associated with gravitational attractions on all body-particles are equal and they are represented by ‘bc’, ‘ef’, ‘hi’ and ‘km’.

If the body-particles were free to move downwards, their resultant motions would have corresponded to resultant additional work associated with them, along lines ‘jm’, ‘gi’, ‘df’ and ‘ac’. Considering body-particles along a radial line (at the centre of figure), magnitudes of resultant additional works associated with them (corresponding to probable displacements) in downward direction are shown by lines ‘p’, ‘q’, ‘r’ and ‘s’.

Magnitude of ‘p’ < magnitude of ‘q’ < magnitude of ‘r’ < magnitude of ‘s’.

Downward deflections of body-particles’ probable paths increase as their distances from outer periphery reduce. Tendency for unequal vertical displacements of body-particles create internal pressure within the fluid macro body. To reach equilibrium, surface of the fluid macro body will assume appropriate curved shape. Body-particles nearer to centre of rotation have lesser downward pressure on them. Body-particles farther from the centre of rotation have greater downward pressure on them. Body-particles nearer to outer periphery will depress by greater magnitude to raise body-particles nearer to centre of rotation to form convex shape on the surface of the fluid macro body.

Part B of figure 2 shows part of the surface cross section with its left-hand side towards the centre of rotation. XX is a radial line on the surface, when the fluid macro body is not spinning. ‘p’, ‘q’, ‘r’ and ‘s’ shows the probable depth to which the surface could be depressed. Curved line ‘yy’ shows the probable surface, when the fluid macro body is spinning. Since the volume of fluid macro body cannot be reduced, surface of the macro body on one side of centre of rotation will reach a resultant level as shown by curved line, YY. Right-hand side of the figure is towards the periphery and left-hand side of the figure is towards the centre of rotation.

Consider the case, where the rotating effort is applied uniformly throughout the fluid macro body. Angular speeds of all body-particles in the rotating fluid macro body will be equal. Fluid macro body’s surface tends to remain flat. No curvature will be created at the surface due to gravitational attraction towards larger macro body. However, outward radial component of linear motion along the circular path will cause body-particles of the fluid macro body to spread outwards. If a rigid container restricts outward spread of the fluid macro body, ‘centripetal force’, created at the restriction will produce subsequent internal compression of the fluid macro body to curve fluid body’s upper surface in concave shape. If the rotating fluid macro body in the container is situated in free space (where the fluid macro body is not influenced by presence of any other large macro body), both free surfaces (perpendicular to plane of rotation) of the fluid macro body will tend to form concave shapes.

Motion in circular path:

Mechanism of motion, envisaged in ‘Hypothesis on MATTER’, explains motion of a macro body in circular path without the assumption of ‘centrifugal force’ and with respect to an absolute reference frame. Currently, due to lack of an absolute reference, we are unable to determine true parameters of a macro body’s motion. It is also understood that state of motion of a macro body has certain effects on its body-parameters. (E.g. Contraction of a macro body’s length in the direction of its motion.) Hence, it should be (at least, theoretically) possible to assess true parameters of motion of a macro body by checking symmetry of its body shape.

In order to sustain a macro body’s motion in a circular path, in a system unaffected by external influences, three conditions should be satisfied. First, the macro body should have a linear motion at a constant speed. Second, a constant external effort (‘centripetal force’) should act on the body, in perpendicular direction to and towards the centre of circular path at all times. Third, at any instant, instantaneous linear speed and future linear speed of the macro body should be equal and constant. These conditions can be satisfied only in systems as shown in figure 3.

In figure 3, a linearly moving macro body is currently at position O: OA is instantaneous displacement of the macro body (in magnitude and direction) in unit time, due to its present linear speed. Y’Y is instantaneous displacement of the macro body (in magnitude and direction) in unit time under acceleration due to ‘centripetal force’ F. OB is the instantaneous displacement of the macro body in unit time (in magnitude and direction) due to its future linear speed and OC is its average displacement in unit time. OC is along the tangent to curve POBT at O. POBT is part of its circular path and XX is the tangent to curved path at O.

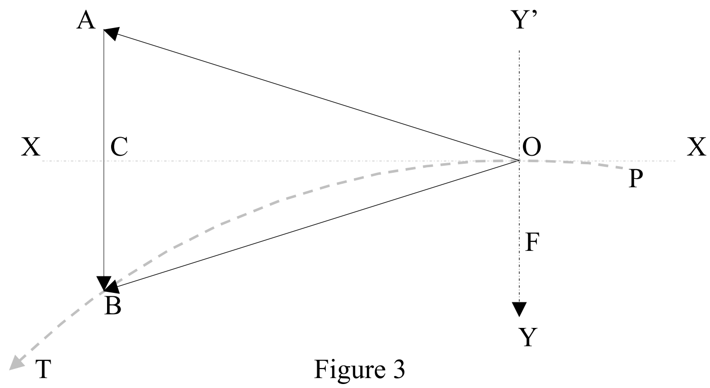

Figure 3

From the figure 3, it can be seen that the direction of instantaneous linear motion of a macro body, moving in a circular path, is deflected outwards from the tangent XX to the circular path. [Reason as to why instantaneous linear motion appears tangential to circular path is given below]. Magnitudes of instantaneous displacements due to present and future linear speeds are equal and their directions are angularly deflected equally in opposite directions from the tangent XX to the path at the current location of the macro body. Magnitudes of angular deflections are proportional to macro body's 'centripetal acceleration' and the curvature of its circular path.

A system of displacements, as shown in the figure 3, is essential to maintain circular path of the moving macro body. Magnitude of resultant displacement, OB, due to present instantaneous motion of the macro body, OA, and motion due to 'centripetal force', AB, is equal to magnitude of displacement that would have been the result of present instantaneous motion of the macro body under inertia. There is no need for an imaginary centrifugal force in the system to account for macro body's departure away from centre of circular path. The departure is due to deflection of macro body's current linear motion from tangent to the circular path, XX. Displacement due to 'centripetal force' not only accounts for neutralisation of outward departure of the body's path from the tangent, but also accounts for the body's inward departure from the tangent to maintain circular nature of its path.

Momentum and motion in circular path:

Momentum is the product of 'real mass' of a macro body (equivalent to its matter content) and its absolute velocity. Mass of a body is likely to change corresponding to magnitude of its absolute linear speed even without a change in its matter content. Linear speed in relative reference frame is an observed quantity with respect to another body, which may be moving in any direction at any linear speed. Therefore, momentum of a body calculated in any relative reference frame has no relevance to true parameters of the body. A change in momentum, according to (Newton's) second law of motion, is the product of (constant) magnitude of 'force' and the time duration of its action on a body. In the concept, used in this article, 'force' is the rate of additional work invested with a macro body by an external effort. Hence, considering in absolute terms, momentum of a body is proportional to total additional work in association with a macro body. The momentum of a rigid body is the sum of the momenta of all particles in the macro body. Being proportional to velocity, momentum is a vector quantity. It has both magnitude and direction. Although additional work associated with a macro body is a scalar quantity, its actions are directed in the direction of its cause, the external effort. Additional work is transferred in the direction of external effort that caused it.

Consider a small macro body O, moving in circular path around a central point, to which the macro body is attached by a rigid link or string OY, as shown in Figure 4. At any instant, natural motion of the macro body is in a straight line, slightly deflected outward from the tangent, XX, on its path. Action of the 'centripetal force' displaces the macro body sideways (towards centre of rotation) during its travel, to curve its path. Figure 4 (not to scale) represents displacements of the macro body in unit time. It shows the macro body at point O in its circular path, POBT. XX is the tangent to circular path at O. OA is macro body's instantaneous linear speed. OY is its displacement due to centripetal acceleration in unit time.

As the macro body is moving in a circular path, its future position at the end of unit time is at B.

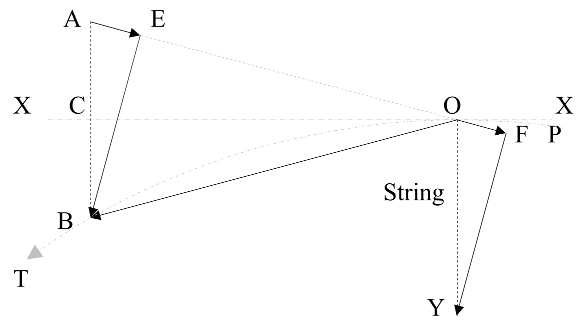

Figure 4

However, inertial action on the macro body tends to take it to position A. This can be permitted only by an extension of the rigid link. Therefore, natural inertial motion of the macro body due to its linear momentum appears to attempt to increase length of the rigid link. Attempt to increase length of the link is assigned to the imaginary 'centrifugal force'. Attempted action by the 'centrifugal force' is nothing but an apparent action derived from macro body's linear motion. The inter-particle 'field force' that maintains the rigidity of the link resists attempt by the linear motion to extend length of the link. This resistance acts to pull the macro body inward, towards the centre of rotation of the path. Since the production of reaction involves structural changes in the matter field of the link, it is a real effort. This external effort acts on the macro body to curve its path. It is called a 'centripetal force'.

Resolve the displacement, OY, produced by the 'centripetal force' into two components, one component, OF, in line with the linear motion of the body, OA, and the other, FY, perpendicular to the linear motion, OA. Component, OF, in line with the linear motion is in opposite direction and hence its action is to reduce the linear speed of the macro body. The other component, FY, acting perpendicular to linear motion, displaces the macro body to its new position, B, on the curved path.

The component of action of 'centripetal force', OF = AE, that is against the linear motion of the macro body, tends to reduce macro body's linear momentum. It invests additional work with the macro body in opposite direction to additional work, which produces macro body's inertial motion in straight line OA. Additional work corresponding to OF neutralises part of inertial motion OA by a magnitude corresponding to AE. Total additional work in association with the macro body is reduced to correspond to OE.

At the same time, perpendicular component of action of 'centripetal force', FY = EB, displaces the macro body to a new position, B. By doing so, the macro body's momentum is restored to a value corresponding to macro body's current linear motion, OB, which is the same as macro body's momentum corresponding to its original linear motion, OA. Additional work, corresponding to component FY of action of 'centripetal force', EB, adds to remaining additional work, corresponding to OE. Total magnitude of additional work in association with the macro body now corresponds to OB, which is equal to magnitude of additional work, originally associated with the macro body. Combining additional work corresponding to FY, which is perpendicular to additional work corresponding to OE, displaces the macro body to position B on the circular path. In motion along a circular path, macro body's momentum is kept constant irrespective of continuous action of a 'centripetal force' to accelerate it towards centre of macro body's circular path.

Linear momentum:

Linear momentum of a macro body corresponds to the magnitude of additional work associated with it. As long as magnitude of associated additional work remains constant, momentum of the macro body does not change. A change in the matter content of the macro body will be reflected by a corresponding variation in its linear velocity. State of motion of a macro body depends on the magnitude of additional work associated with it. (Intrinsic work associated with a macro body develops and sustains the integrity of its 3D matter particles and whole body as a single unit). Magnitude of additional work, associated with a macro body remains constant unless changed by actions of external effort. This tendency gives rise to the phenomenon of 'conservation of linear momentum'. A change in the matter content of a macro body cannot vary, additional work associated with it [1].

Additional work, associated with a macro body, in the universal medium can be transferred only in straight line. State of motion of a macro body, corresponding to certain additional work, can remain steady only as long as the macro body (as a whole) is not deflected away from the line of transmission of the additional work (its matter field). If the macro body is deflected away from this straight line, part of additional work will be lost and the macro body's velocity will reduce. If the macro body is deflected from its line of straight-line motion by action of another external effort, the macro body will move in a resultant direction, while losing whole or parts of additional works in both directions. Current motion of body-particles of macro body will create additional work corresponding to the resultant motion in association with the macro body to change macro body's momentum to correspond to its present state of motion.

A real external effort – the 'centripetal force' – continuously acts on a macro body, moving in circular path. Action of this external effort is to introduce additional work in association with the macro body. At the same time, due to macro body's constant change of direction of motion, it loses additional work associated with its linear motion at the same rate as the macro body receives additional work. Therefore, magnitude of additional work, associated with the macro body moving in circular path remains constant. Continuous action by constant magnitude of 'centripetal force' preserves constancy of linear speed and linear momentum of a macro body in its circular path. Magnitude of original inertial action on the macro body is preserved.

Work, constituted by distortions in universal medium, can be transferred only in straight lines. Additional work, producing inertial motion of a macro body at constant linear speed is transferred in straight line in the direction of its instantaneous linear motion. Change of direction of the macro body from its straight-line motion due to action of 'centripetal force', moves the macro body (partially) away from the region of the distortions in universal medium, producing the macro body's linear motion. Reduction in additional work reduces macro body's linear speed. However, additional work invested by the action of 'centripetal force' compensates for this loss and restore the magnitude of total additional work associated with the macro body. This is indicated by constancy of instantaneous linear speed of the macro body. Although there is a loss of additional work associated with the macro body moving in circular path, at a constant rate, it is restored at the same rate by the action of 'centripetal force'. This prevents any change in the linear momentum of the macro body, moving in a circular path.

Reduction in 'centripetal force':

Reduction in the magnitude of 'centripetal force' reduces its action on the macro body. Less additional work is invested with matter field of the macro body. The macro body fails to deflect its path to suit motion in original circular path, as shown in figure 5. OY is the motion due to action of reduced 'centripetal force'. OF, the resolved component of OY, acts in opposition to OA to reduce its magnitude to OE, which is more than magnitude of OE in figure 4.

Macro body loses less additional work associated with its original inertial motion. Lower magnitude of additional work (invested with matter field of the macro body by reduced 'centripetal force') reduces deflection and magnitude of its resultant motion, OB, from original inertial motion, OA. OB shows the resultant motion of the macro body in magnitude and direction. Macro body's new path, POBT, is deflected less from the direction of its instantaneous linear motion, OA. Outward deflection of instantaneous inertial motion moves the macro body away from the centre of rotation to enlarge its circular path. Radius of circular path increases.

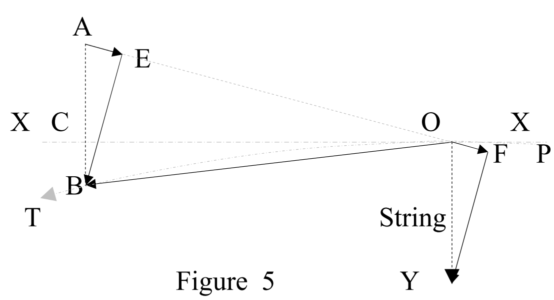

Figure 5

Magnitude of OB is less than that of OA. Instantaneous linear speed of the macro body is reduced.

Matter content of the macro body being the same, a reduction in its linear speed reduces macro body's linear momentum. Reduction in 'centripetal force' on a macro body moving in circular path, increases diameter of the circular path with corresponding reduction in macro body's linear speed and linear momentum. Both these factors subscribe towards reduction in macro body's angular speed in its circular path.

Increase in 'centripetal force':

An increase in the magnitude of 'centripetal force' enhances its action on the macro body. More additional work in invested with matter field of the macro body. The macro body deflects its path by greater magnitude than that is required to suit motion in original circular path, as shown in figure 6. OY is the motion due to action of enhanced 'centripetal force'. OF, the resolved component of OY, acts in opposition to OA to reduce its magnitude to OE, which is less than magnitude of OE in figure 4.

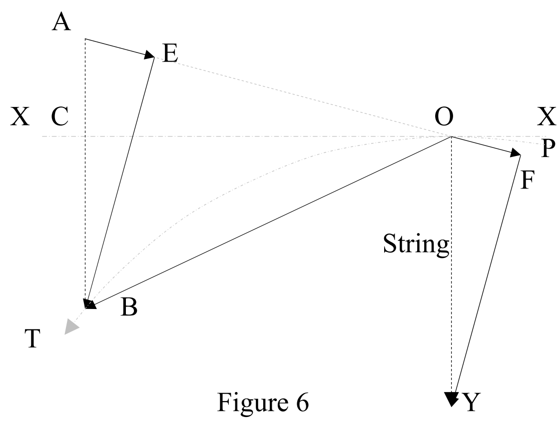

Figure 6

Macro body loses more additional work associated with its original inertial motion. Greater magnitude of additional work (invested with matter field of the macro body by enhanced 'centripetal force') increases deflection and magnitude of its resultant motion, OB, from original inertial motion, OA. OB shows resultant motion of the macro body in magnitude and direction. Macro body's new path, POBT, is deflected more from the direction of its instantaneous linear motion, OA. Inward deflection of instantaneous inertial motion moves the macro body towards the centre of rotation to contract its circular path. Radius of circular path reduces.

Matter content of the macro body being the same, an increase in its linear speed enhances macro body's linear momentum. Increase in 'centripetal force' on a macro body, moving in circular path, increases magnitude of resultant instantaneous linear speed of the macro body and reduces diameter of its circular path. Macro body's linear momentum will increase corresponding to its linear speed. Both these factors subscribe towards enhancement in macro body's angular speed in its circular path.

Similar arguments hold good for linear momenta of every body-particle in a rotating body. In this case, 'centripetal force' on body-particles is continuously present, even when the macro body is not rotating. It keeps the integrity of the macro body.

Angular momentum:

Angular momentum is a property related to a rotating macro body (or a macro body moving in circular path) representing its rotational inertia about an axis. It shows the ability of the macro body to continue its angular motion at a constant rate, presumably, without external torque on it. Since all inertial motions are in straight lines, to move a macro body in circular path, it is imperative that a 'centripetal force' of constant magnitude should act continuously on the macro body. Although parameters of circular motion appear to be steady, theoretically, it cannot be termed as a steady state of motion. Continuous action of 'centripetal force' necessitates uninterrupted linear acceleration of the macro body towards its centre of rotation. Angular momentum can be sustained only as long as the action of 'centripetal force' is present. Hence, angular momentum is an assumed quantity under imaginary conditions. In order to satisfy 'balance of efforts' during a steady state of angular motion, real 'centripetal force', (acting continuously on a body moving at a constant angular speed) is neutralised by an imaginary 'centrifugal force' in opposite direction. This may help mathematical derivations but does not represent reality of actions. Angular momentum is a vector quantity, requiring the specification of both a magnitude and a direction for its complete description.

Motion on circular path:

In cases of macro bodies moving in circular path, magnitude of the angular momentum is equal to product of its linear momentum (product of its mass m and average linear velocity v) and perpendicular distance 'r' from the centre of rotation to the line in the direction of body's average linear motion and passing through its centre of gravity.

Magnitude of angular momentum, L, of a macro body moving in a circular path; $L = m\, v\, r$.

where 'm' is the mass (representing matter content of macro body), 'v' is macro body's average linear speed and 'r' is radius of its circular path.

Use of 'r' in the equation facilitates to ignore continuous action the external effort – the 'centripetal force' – on the macro body. Changing the magnitude of 'centripetal force' on the macro body moving in circular path vary magnitude of its average linear speed 'v' and radius 'r' of its circular path. Currently, continuous action of 'centripetal force' (which is neutralised by assumed action by imaginary 'centrifugal force') is ignored and change in magnitude of radius 'r' is considered as the cause of change in average linear speed of macro body. This phenomenon is the basis of 'law of conservation of angular momentum'.

To find real angular momentum of a macro body, moving in circular path, it is necessary to consider parameters of the macro body and parameters of its motion in absolute terms. Only the real angular momentum can be considered as proportional to total additional work associated with the macro body. By considering additional work associated with matter field of the macro body as the basis, radius of the circular path will not appear in the equation. Radius of curvature of the path, R, may be calculated from macro body's angular speed, ω, and average linear speed, v, in absolute reference frame.

$$R = v / \omega$$

Angular momentum of a macro body, moving in circular (curved) path is derived by relating its linear momentum to an axis perpendicular to the plane and through centre of its curved path. No singular macro body can remain static in space. Therefore, all references with respect to macro bodies are relative references. Parameters of a macro body moving in circular path in relative reference frame cannot give its real angular momentum, corresponding to total additional work associated with it. A circular path in relative reference frame will not be a circular path in absolute reference frame. Behaviour of an independent macro body corresponds to its real parameters and real parameters can be obtained only in absolute reference frame. Angular momentum of a macro body moving in circular path will become zero on termination of action by 'centripetal force' on it. The macro body will be left only with its linear momentum. In other words, its angular momentum is not conserved. It will last only as long as the 'centripetal force' is active on it.

Rotary motion:

Generally, macro bodies in solid state have higher viscosity. This keeps the integrity of the body under usual conditions. Hence, every body-particle in a rotating solid macro body moves in circular path about its centre of rotation. Viscosity of the body-material provides ample 'centripetal force' on the body-particles to keep them in their circular paths. As this 'centripetal force' is inherent in the solid macro body, its actions are usually ignored, unless spin speed of the macro body is very high or radial size of the macro body is very large.

In cases of spinning macro bodies, angular momentum is derived by relating linear momenta of all its body-particles to an axis of rotation through the macro body. Sum of angular momenta of all body-particles gives the angular momentum of the macro body. It is equal to the product of the moment of inertia of the body about the axis of rotation and the angular velocity of the body. Angular momentum is not one of macro body's real parameter. Moment of inertia of a macro body depends on the location of its axis of rotation. Magnitude of angular momentum depends on the choice of observer in selecting the axis of rotation. It is related more to relative location of macro body's spin axis than to the macro body. Being proportional to velocity, linear momentum has direction; consequently, when a body in plane motion rotates, the momentum of each particle has a moment about any point in the plane. The sum of these moments of momenta is called the angular momentum of the body about that point.

Angular momentum characterizes rotary inertia of the macro body about its axis of rotation. Since whole-body-linear motion of a spinning macro body is not usually considered during determination of its angular momentum, such angular momentum corresponds to relative reference frame with respect to centre of rotation of the macro body. Centre of rotation of the macro body is assumed static in space. In a rotating integral macro body, ‘centripetal force’ is provided by adhesion within it. Since this effort is always present, as long as the rotating macro body maintains its integrity, magnitude of its angular momentum obeys law of conservation of angular momentum.

If a macro body’s axis of rotation is outside the body, angular momentum of the macro body has to be considered as in the case of angular momentum for bodies moving in circular path (described in above paragraph). In cases of spinning macro bodies moving in curved paths, their angular momentum due to spin motion, angular momentum due to motion in curved path and momentum due to linear motion remain distinctly separate. In each case, additional work associated with it maintains its distinctive identity in macro body’s matter field. Changes in any one of them cannot vary the other two. However, motion of the macro body may appear to be a resultant of all motions.

Circular path in absolute reference frame:

In calculations involving a macro body’s motion in a circular path, effects of inertia associated with ‘centripetal force’ on the macro body after its termination are not usually taken into consideration. It is assumed that as soon as the ‘centripetal force’ is terminated, all effects due to the effort also cease. This belief is based on observed path of a particle detached from the rim of a rotating wheel (or similar phenomena). The detached particle appears to move in the direction tangential to its path, at the point of its detachment. This is only an apparent phenomenon and it is not the true direction of particle’s instantaneous motion, until it is stabilised as a straight-line path. It takes inertial delay for an external effort to stabilise its effect on a macro body. Only after the inertial delay, the macro body will reach its stable state of motion. Hence, it is only logical to think that the termination of an external effort also takes similar inertial delay to stabilise its effect on the macro body.

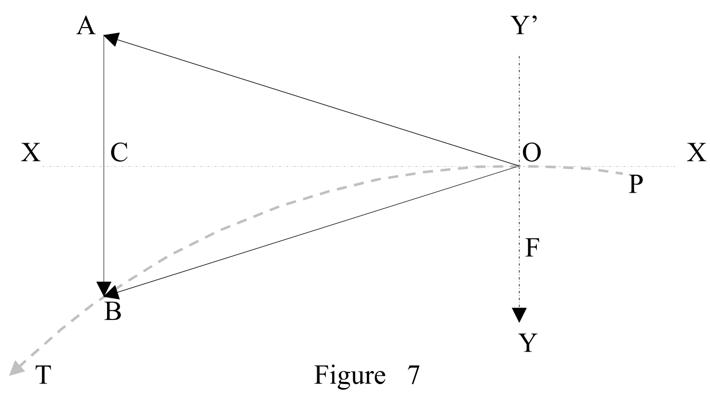

Figure 7

Figure 7 represents motion of a very small macro body along the circular path POBT. Point O represents a small macro body. Work is invested into matter field of the macro body by the continuous action of ‘centripetal force’ (along the arrow Y’OY – shown as a pull-force) towards the centre of curvature of its path. Y’Y is the direction of macro body’s centripetal acceleration. Due to curvature of the path, direction of ‘centripetal force’ with respect to the macro body’s direction of motion changes continuously. In the absence of centripetal acceleration, the macro body would have reached point A, at the end of unit time. However, centripetal acceleration of the macro body causes its displacement to point B at the end of unit time. Resultant motion of the macro body is along OB and magnitude of resultant speed of the macro body is represented by length of OB. Average linear speed of the macro body, given by the average of linear speeds OA and OB, is equal to OC = v. Angle between the tangent OC and direction of resultant motion OB is taken as the angular speed, ω, of the macro body.

Radius of curvature of circular path, $R = v / \omega$ (for very small values of ω)

F is the magnitude of 'centripetal force', m is the mass of the macro body, representing its matter content and 'a' is the macro body's centripetal acceleration. Additional work introduced by 'centripetal force' is equal to its action on the macro body, which is proportional to its acceleration, a, in the direction of the effort. Considering motion of the macro body in absolute reference frame (an inertial reference frame with respect to universal medium);

$$a = F \div m$$

Additional work introduced by 'centripetal force' is equal to its action on the macro body, which is proportional to its acceleration, a, in the direction of the effort. Magnitude of additional work done about the macro body (in perpendicular direction to its circular path) in unit time, due to centripetal acceleration;

$AB = a \div 2$ (ignoring the constancy of proportion and putting, t = unit in equation; displacement = $at^2/2$)

At the end of unit time, the macro body is displaced to position, B, which is the result of original additional work associated with macro body's inertia and the additional work introduced by 'centripetal force' in unit time.

Let OA represent macro body's present instantaneous linear velocity, V, at O.

OA = V units and AB = a / 2 units

As long as the linear speed of a macro body and its centripetal acceleration remain constant, the macro body moves in a circular path. It appears to be in a steady state of motion. At the same time, system of efforts on the macro body is not balanced and magnitude of external effort on the macro body is not nil. To move in a circular path, macro body's instantaneous linear speeds at all points on the path remain the same, while magnitude of external effort also remains constant. Therefore, in circular motion, a macro body can appear to be in a steady state of motion even while it is under the action of an external effort.

Therefore, future instantaneous linear speed, $OB = OA = V$

Average linear velocity of the macro body, OC = v, which is tangential to circular path at O.

In right-angled triangles AOC and BOC; Side OC is common to both, Side OA = Side OB, Angles ACO and BCO are right angles.

The triangles are similar; Side AC = Side BC

Angle AOC = angle BOC = Angle AOB / 2 = angular speed of the macro body.

Since AB = a / 2, AC = BC = a / 4 **(2)**

Average linear speed of the macro body along the tangent, $v = V \cos \omega$

The macro body continues to move in a circular path. Direction of its present instantaneous linear motion, OA, is deflected away from the tangent XX, by an angle equal to its angular speed.

Magnitude of 'centripetal force':

Consider a macro body of constant linear speed, moving in a circular path, as shown in figure 8. Let OA represent magnitude of additional work in association with the macro body's inertia or the macro body's instantaneous present linear speed, V. AB is magnitude of additional work introduced or macro body's displacement due to action of 'centripetal force', Y'Y. OB is the resultant additional work in association or instantaneous resultant linear speed of the macro body. Since OA = OB, the macro body travels in a circular path, POBT. OC is the macro body's average (tangential) speed, v, at any point on its circular path.

Let AC = CB = d units, AB = 2d units/sec, OA = OB = V units/sec, OC = v units/sec,
$\angle AOC = \angle COB = \omega$ rad/sec, $\angle AOB = 2\omega$ rad/sec.

Angular speed of the macro body in the circular path is measured with respect to tangents to the path.

Angular speed of macro body, $\angle COB = \omega$ rad/sec

Total angular deflection of macro body's path from OA to OB, $\angle AOB = 2\omega$ rad/sec

From triangle AOC; $v \div V = \cos \omega$, $V = v \div \cos \omega$

$$d^2 + v^2 = V^2 = v^2 \div \cos^2 \omega$$

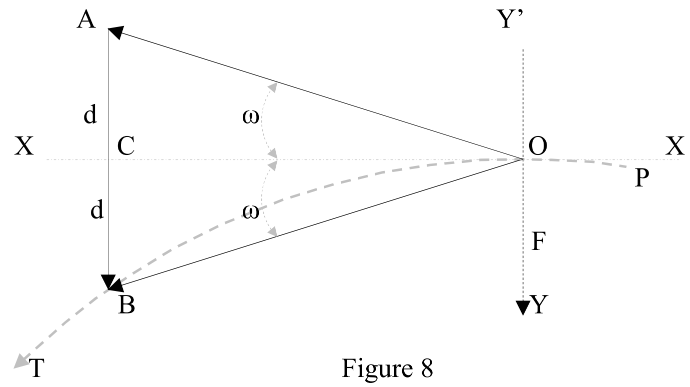

Figure 8

$$d^2 = \frac{v^2}{Cos^2\omega} - v^2 = v^2\left(\frac{1}{Cos^2\omega} - 1\right) = v^2\left(\frac{1 - Cos^2\omega}{Cos^2\omega}\right) = v^2\,\frac{Sin^2\omega}{Cos^2\omega} = v^2\,Tan^2\omega$$

$d = v\,Tan\omega$, Total radial displacement = $2d = 2v\,Tan\omega$

Let the 'centripetal acceleration' = a units/sec^2

Total displacement in unit time, $2d = a\frac{t^2}{2} = \frac{a}{2}$ (putting time, t = unit measure)

$$\therefore \frac{a}{2} = 2v\,Tan\,\omega, \quad a = 4v\,Tan\,\omega$$

Considering the action in inertial reference frame; External effort, F = m a

where 'F' is the magnitude of 'centripetal force' (external effort), 'm' is the mass (neglecting effects of linear speed on mass of the macro body) and 'a' is the linear acceleration of the macro body due to 'centripetal force'.

In the case of a macro body moving in circular path, 'centripetal force' is the only external effort, acting on the body. Hence, magnitude of 'centripetal force' acting on the macro body;

$$F = ma = 4mv\,Tan\,\omega \qquad \textbf{(3)}$$

'Centripetal force' of this magnitude alone can maintain circular path of the macro body. There is no need for an assumed 'centrifugal force'. Linear speed of the macro body should remain constant and constant magnitude of 'centripetal force' must continuously act on the macro body.

If the magnitude of 'centripetal force' is less than (4 mv Tan ω), linear speed of the macro body will gradually reduce and the macro body will move away from centre of its circular path to trace larger circular path. If the magnitude of 'centripetal force' is greater than (4 mv Tan ω), linear speed of the macro body will increase and it will gradually move towards centre of its circular path to trace a smaller circular path.

In rotational reference frame, magnitude of 'centripetal force' (equal and opposite to magnitude of 'centrifugal force') given by equation (1) is F = (mv) ω. This equation is valid only for very small values of angular speeds, ω. Irrespective of magnitude of angular speed, magnitude of 'centrifugal force' is directly proportional to magnitude of angular speed of the macro body. Should the angular speed of macro body approaches or exceeds (π / 2) radians per second per completed circular path, result given by equation (1) becomes illogical.

In inertial reference frame, magnitude of 'centripetal force' is given by equation (3) as [$F = (mv)\,4\,Tan\,\omega$]. This value may be taken as equivalent to the assumed 'centrifugal force' on the macro body. Here, magnitude of 'centripetal force' is related to the linear momentum of the macro body by a factor (4 Tan ω). Relation to 'tangent of angular speed' limits the action of 'centripetal force' to macro bodies with angular speeds below (π / 2) radians per second per each completed circular path. When angular speed of the macro body approaches (π / 2) radians per second per each completed circular path, magnitude of ‘centripetal force’ will approach infinite proportions. This shows that as the direction of external effort become perpendicular to the direction of linear motion of the macro body, additional work associated with the macro body and producing its linear motion will be lost to the macro body. Macro body’s original linear motion will be lost. The macro body will be displaced in perpendicular direction to its original linear motion. It will no more respond to lost additional work from its matter field. Therefore, angular speed of a macro body moving in circular path is limited to much less than (π / 2) radians per second per each completed circular path.

If a spinning macro body is a mixture of different material-particles of unequal densities and of irregular sizes, body-particles of higher matter contents (mass) tend to have outward radial motion at higher speed, compared to body-particles of lower mass. By equation (3), ‘centripetal force’ required to keep a body-particle in its circular path is proportional to its mass. Magnitude of ‘centripetal force’ that can be provided by a macro body depends on its consistency and it is common to all its body-particles. For two body-particles of different masses, moving in the same circular path about macro body’s centre of rotation, ‘centripetal force’ required by each of the body-particles is proportional to its mass. As the magnitude of ‘centripetal force’ on all body-particles of the macro body is same, heavier body-particles tend to enlarge their circular paths, by moving away from the centre of rotation. Outward motion of heavier body-particles is due to lower magnitude of ‘centripetal force’ on them than that is required to keep their circular path stable rather than due to action of fictional ‘centrifugal force’ on them. This is the working principle of centrifuge mechanisms.

On termination of ‘centripetal force’:

We shall consider effects, when action of ‘centripetal force’ on a macro body (moving in circular path POBT in figure 8) is terminated, at point O:

During inertial delay, after termination of the ‘centripetal force’, additional work already introduced into matter field of the macro body (at the instant of termination of ‘centripetal force’) continues to accelerate the macro body towards the centre of its circular path. Since the ‘centripetal force’ is now terminated, magnitude of original acceleration due to additional work, introduced by ‘centripetal force’, is gradually reduced. This action will continue until all the acceleration components of the additional work, introduced by the (now-removed) ‘centripetal force’ are lost from macro body’s matter field. As the magnitude of acceleration becomes zero after inertial delay, we can take the average magnitude of acceleration during the inertial delay is equal to half the value of acceleration during the action of the ‘centripetal force’.

Let the magnitude of additional work in the matter field, due to ‘centripetal force’, in steady state of macro body’s motion in circular path = W

Magnitude of additional work, in the matter field of macro body due to ‘centripetal force’, at the instant of termination of ‘centripetal force’ = W

Magnitude of additional work in the matter field of macro body, due to ‘centripetal force’, at the end of inertial delay = 0

Average magnitude of additional distortions, due to ‘centripetal force’, during inertial delay = W/2

Centripetal acceleration is proportional to magnitude of additional work in macro body’s matter field.

Average centripetal acceleration during inertial delay = a/2

Let the inertial delay = t units of time

Using the equation of linear motion, displacement = $\frac{1}{2} at^2$, where ‘a’ is the linear acceleration; and ‘t’ is the time interval.

Displacement of the macro body, due to reduced centripetal acceleration after termination of ‘centripetal force’, during inertial delay = $a\, t^2 / 4$

The macro body attains its steady state of motion on completion of acceleration period and in the mean time; the macro body is displaced by a distance, ($a\, t^2 / 4$), to point C on the tangent XX through point O on the circular path. At point C, the macro body has no action on it by terminated ‘centripetal force’, to curve its path. The macro body will continue to move in a steady state of linear motion under linear inertia associated with it along OC, which coincides with the tangent to the curve at point O. This is the reason, why a macro body moving in circular path or a body-particle from a rotating macro body released from 'centripetal force' moves in tangential direction to its circular path. Original direction of macro body's instantaneous present linear motion is along OA, which is deflected outward from the tangent, XX. Angular deflection of direction of the instantaneous linear motion, OA, creates an illusion that the body is trying to move away from centre of curvature of the circular path. This apparent attempt is assigned to the action of imaginary effort, the 'centrifugal force'. Imaginary forces cannot act on a real body.

Tangential motion:

At any instant, a body-particle, O, (in figure 9) at the periphery of a spinning wheel simultaneously has two motions. (Here, a very small part of the body-material is taken as a unit body-particle and motions of its individual constituents within the spinning wheel are ignored). One motion, OA, displaced by an outward angular deflection from the tangent, XX, is provided by its linear speed along circular line, POBD. Another linear motion, OE, is the displacement provided by 'centripetal force' due to viscosity of body-material, which maintains the integrity of the macro body. Cause of 'centripetal force' may be any or all of various actions by efforts by gravitation and 'field forces'. The 'centripetal force' accelerates the body-particle towards the centre of rotation of the spinning wheel. In this state, the system is stable and the particle at the rim of the wheel moves in a circular path relative to the centre of rotation of the wheel. The particle has constant linear speed; it is simultaneously under constant radial velocity and constant radial acceleration. (Similar to 'motion under central force' [6]). The word 'constant' indicates that the numerical values of speed, velocity and acceleration do not vary.

In figure 9, grey curved line POBD shows part of circular path of a body-particle O. Present instantaneous linear motion of the body-particle at O is represented by arrow, OA, which is equal to V (being displacement in unit time). Instantaneous lateral motion a/2, due to 'centripetal force' is represented by arrow, OE. Line XOX is the tangent to the circular path at O. Resultant instantaneous motion of the body-particle, along its circular path, POBD, is shown by the arrow, OB.

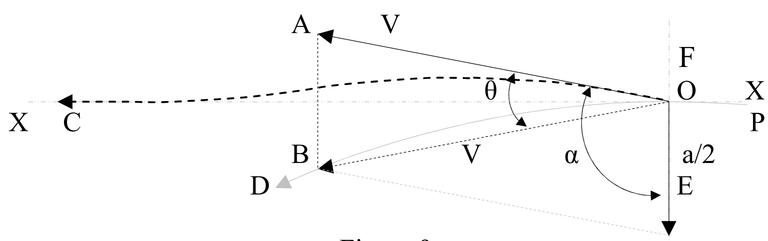

Figure 9

$$AB = OE = a/2, \quad OA = OB = V, \quad \angle AOB = \theta, \quad \angle AOE = \alpha$$

By parallelogram law of forces,

$$OB^2 = OA^2 + OE^2 + 2 \times OA \times OE \times Cos\angle AOE$$

$$V^2 = V^2 + \left(\frac{a}{2}\right)^2 + 2V\frac{a}{2}Cos\alpha, \quad \left(\frac{a}{2}\right)^2 = -2V\frac{a}{2}Cos\alpha, \quad a = -4VCos\alpha$$

$$\frac{a}{4V} = -Cos\alpha, \quad Cos(180-\alpha) = \frac{a}{4V}, \quad \alpha = 180 - Cos^{-1}\frac{a}{4V}, \quad \angle AOP = \frac{\theta}{2} = \alpha - 90$$

Substituting the value of α,

Outward deflection of present instantaneous linear motion from the tangent to the curved path;

$$\frac{\theta}{2} = \left(180 - Cos^{-1}\frac{a}{4V}\right) - 90$$

$$\frac{\theta}{2} = 90 - Cos^{-1}\frac{a}{4V} \text{ degrees} \qquad \textbf{(4)}$$

Let the body-particle break away from the rotating wheel, when it reaches the point O. Linear speed tends to carry the particle in the direction, slightly deflected outward from the tangent to the circular path, by (θ/2) degrees. At the instant of detachment, the body-particle is also under the 'centripetal force' and this effort has been providing body-particle's radial acceleration. When the unity of the body-particle with the wheel is lost, 'centripetal force' is no more present, on the body-particle. However, radial acceleration, provided by the 'centripetal force', takes some time to die away. This is the inertial delay. If the inertial delay is taken as unit time, displacement of the body-particle in radial direction, i.e., towards the tangent is numerically equal to half the magnitude of radial acceleration. In other words, direction of motion of the detached particle is brought along to the tangential line during the inertial delay and by the action of 'centripetal force' that existed at the instant of detachment. Curved dashed arrow OC, in figure 9, shows the approximate path of the body-particle after it broke away from the rotating wheel until it achieves a steady state of motion along the tangent, XX, to the circular path at O. If the body-particle were originally moving along the tangent to the rim, you would see the body-particle flying away from the rim along a path that is deflected inward from the tangent. This does not happen.

Generally, the component of linear motion of the body-particle (deflected outward from the tangent), perpendicular to the tangent is attributed to the imaginary 'centrifugal force'. In such case, the present instantaneous linear motion of the body-particle is assumed to be in tangential direction to its circular path, same as its average linear motion.

Radius of stable galaxy:

There are no rigid macro bodies. Macro bodies, which have high viscosity, are usually in solid state. They tend to maintain their integrity and shape. Near larger macro bodies, fluid macro bodies tend to adopt the shape of its container. In free space, all fluid macro bodies tend to form spheres. Clouds and debris in deep space gather, under mutual gravitational attraction, to form very large macro bodies. They are mainly gaseous with few solid matter bodies in them. Generally, they can be considered as of fluid nature. A fluid macro body has low viscosity. Inter-particle 'field forces' and mutual (apparent) gravitational attractions between constituents provide adhesion between its body-particles. Actions of these efforts, which continue to reduce size of the fluid macro body is its gravitational collapse. In the course of their formation, due to their (uneven) gravitational collapse, such bodies acquire spin motion about one of the axes through the macro body. Outer regions of the macro body attain greater spin speed about its spin axis, compared to inner regions. If efforts, due to gravitational collapse, moulding a macro body into a sphere are uniform throughout the fluid macro body's surface, the fluid macro body will not gain spin motion.

It is very improbable that radial motions of parts of such a large body of diverse contents (due to gravitational collapse) are uniform in all directions. Uneven radial motions of different parts of the fluid macro body induce its accelerating spin motion. Due to low viscosity, in fluid macro bodies, 'centripetal force' (provided by mutual gravitational attraction between body-particles) is very low. Hence, during spin motion, fluid macro bodies in free space (not restricted by a container) spread outwards from spin axis.

If no additional torque is supplied to the rotating fluid macro body, magnitude of total additional work associated with it remains constant. The fluid macro body should continue to rotate at a constant angular speed. However, changes in its body-parameters are bound to affect fluid macro body's state of rotary motion. As the spinning-fluid macro body expands in diameter, a body-particle at its periphery keep moving away from centre of rotation. If the fluid macro body has to maintain its original angular speed, its body-particles have to move faster in their circular paths. If no additional work is supplied to the fluid macro body, this cannot be accomplished. Additional work with each body-particle remaining constant, linear speeds of body-particles will reduce as they move away from centre of rotation, with corresponding reduction in angular speed of the fluid macro body.

Outward displacement of body-particles will continue until sufficient 'centripetal force' can be provided to arrest their outward displacement. As the total matter content of the fluid body remain same and expansion of its radial size increase, 'centripetal force' can only reduce, rather than increase. Tendency of expansion acts in direct opposition to actions of gravitational collapse. In such a spinning macro body, every body-particle tends move away from the centre of rotation of the macro body due to its angular motion, while 'centripetal force', provided by gravitational collapse tends to move them towards the centre of rotation. Balance between these actions determines future formation of the fluid macro body.

Magnitude of 'centripetal force', F_c, required for a body-particle (situated on the outer periphery) of the spinning fluid macro body, to maintain its motion in a circular path;

$$F_c = 4mv \operatorname{Tan} \omega \qquad \text{(by equation } \textbf{(3)}\text{)}$$

This effort is provided mainly by adhesion due to gravitational attraction between the body-particle and rest of the macro body. By using inverse square law for approximate magnitude of gravitational attraction, F_g;

$$F_g = \frac{MmG}{R^2}$$

Where 'm' is mass of the body-particle, 'M' is mass of rest of the fluid macro body, 'G' is the gravitational constant in 3D spatial system and 'R' is the radius of the fluid macro body, taken as the average distance between the body-particle and rest of all body-particles of the fluid macro body.

For stable state of radial size of the fluid macro body, body-particles (on an average) should move in circular paths. This can be achieved only when magnitudes of 'centripetal force' on them should be as given by equation (3). Hence, a spinning fluid macro body can maintain its radial size constant, only when the gravitational attraction, F_g, is equal to the required 'centripetal force', F_c.

$$\frac{MmG}{R^2} = 4mv \operatorname{Tan} \omega, \qquad \frac{MG}{R^2} = 4R\omega \operatorname{Tan} \omega, \qquad \frac{MG}{4R^3} = \omega \operatorname{Tan} \omega$$

$$\left(\frac{MG}{4}\right)\frac{1}{R^3} = \omega \operatorname{Tan} \omega \qquad \textbf{(5)}$$

For critical equilibrium, radial size of the fluid macro body in the plane of its spin, equation (5) has to be satisfied. In the equation, ω is fluid macro body's spin speed and R is its radius. For a fluid macro body, the term (MG/4) is a constant. Hence, ($\omega \operatorname{Tan} \omega$) is inversely proportional to cube of its radius.

Gravitational collapse and accelerating spin motion of the fluid macro body cannot be stopped. Hence, these actions will continue to change parameters of the fluid macro body. A fluid macro body, like a newly formed galactic cloud, in free space will expand until its angular speed is sufficiently lowered, when 'centripetal force' is sufficient to maintain curvature of its periphery. However, such a body can sustain its stability of radial size only as long as equation (5) is satisfied.

Should the magnitude of angular speed, ω, or radius, R, of the galactic cloud become comparatively more, inward radial motion of body-particles due to gravitational collapse will become too less to compensate for their outward displacement due to their motion in circular path. Matter contents of the galactic cloud will continue to spread outwards in the plane of its spin. As linear speed of body-particles in their circular path approaches the speed of light, body-particles will breakdown to primary particles to form a 'halo' around the equatorial plane of the galactic cloud. Halo, formed around a galactic cloud, tends to arrest its whole-body linear motion towards any other macro bodies and keep it steady in space to form a stable galaxy, for further inner development.

Since a stable galaxy is a spinning fluid macro body, its gravitational collapse and spin acceleration will continue, even after it has attained brief period of stability. Its contents have a constant tendency to spread outward. As diameter of the galaxy increases further and linear speeds of primary particles reach the speed of light, they will breakdown to independent basic 3D matter particles (photons), to be radiated in various directions away from the galaxy. Gradually whole of the galaxy will disintegrate into basic 3D matter particles.

Should the magnitude of angular speed, ω, or radius, R, of galactic cloud become comparatively lesser (or the galactic cloud has no spin motion) during its formation, outward motion of body-particles will become too slow to compensate for their inward radial motion due to gravitational collapse. Galactic cloud will shrink at an accelerating pace to form a single, very dense macro body (black hole), with low spin speed or without spin motion at all. This body has no protection from gravitational attraction towards other macro bodies in space, as in the case of stable galaxy.

Stable size and nature of a galactic cloud (formed in free space by accumulation of inter-galactic clouds and debris) is determined by its spin speed during its formation. With low or no spin speed, such a body will condense to become a 'black hole'. As long as the spin speed of such a body corresponds to equation (5), it will maintain its stability as a galaxy. Should its spin speed exceeds the magnitude given by equation (5), it will gradually disintegrate and lose most of its matter content into free space.

Gyroscopic properties:

A gyroscope is a spinning macro body supported by gimbals, to afford free movements about all coordinate axes. A gyroscope continues to spin at a constant rate and with a fixed orientation of its axis unless influenced by the application of an external effort.

Gyroscopic inertia:

Inertia, associated with a body-particle in a rotating macro body, sustains the body-particle's constant motion in a straight line. Simultaneously, continuous action by 'centripetal force' maintains curvature of body-particle's path by deflecting its path from the straight line of its motion. These two motions, together, determine the absolute plane in which the body-particle moves. As long as no other external efforts are applied to the rotating body, every body-particle in the rotating macro body will continue to move only in absolute plane of its motion. Absolute plane is a plane in the universal medium (that fills the entire space).

Every body-particle of the spinning body of gyroscope moves in absolute plane of its motion. Since the gyroscope has free movements in all coordinate planes, relative movements of its supports do not affect the gyroscope's absolute plane. All body-particles of the gyroscope will maintain their motion in absolute planes and maintain direction of its spin axis. This tendency gives rise to the property of 'rigidity in space' to gyroscope's spin axis. Spin axis of a gyroscope tends to maintain its direction steady in space irrespective of any movements of its support mechanism. Rigidity of gyroscope's axis in space tends to resist any attempt to deflect it from its stable orientation. This phenomenon is known as 'gyroscopic inertia' due to the reluctance shown by gyroscope's axis to act according to an external effort applied to it. Gyroscopic inertia is not due to any special nature of the spinning macro body but due to the gimbals which allows free movement of the spinning macro body in all coordinate planes.

Gyroscopic precession:

A body-particle in the spinning macro body of a gyroscope moves in an absolute plane in space. An external effort on it tends to change its direction of motion and thereby change the absolute plane of its motion. Any such change is with respect to the axis passing through the point of application of external effort. An external effort, applied on the spinning macro body of a gyroscope at a point away from the spin axis and in a direction perpendicular to plane of its spin motion, produces its result in a plane perpendicular to both, the macro body's rotational plane and the plane of action of external effort. Action will appear (π / 2) radian ahead of point of application of external effort, in the direction of spin motion. This phenomenon is known as 'gyroscopic precession'.

Rectangle G in figure 10A shows the spinning macro body of a gyroscope (looking from the top). XX is the macro body's spin axis. O represents a body-particle at the top most part of outer periphery. Direction of average motion of this body-particle, OV, is along the tangent to macro body's periphery at O. Let an external effort, F, act on the body-particle at point O on macro body's periphery. Work, introduced by the external effort, acts to deflect the (already-moving) body-particle's direction of motion, in the direction of effort. OV represents linear motion of the body-particle in its circular path. F_1 represents movement of the body-particle due to action of external effort, F. Resultant of these two independent motions is directed along OR. OR is deflected from OV by angle θ. All body-particles passing through location O are identically deflected. Integrity of the macro body compels it to turn itself in the direction of deflection, so that spin axis of the macro body is deflected from XX to $X_1 X_1$ with angular difference of θ.

Same spinning macro body is represented in its plane of rotation by the ellipse G in figure 10B. Macro body rotates in the direction of curved arrow. Axis of spin is XX. External effort F is applied to the top-most point on the vertical line passing through the centre of rotation. Due to gyroscopic precession, external effort will appear to act in the horizontal plane at F_1. This action will turn the spinning macro body in horizontal plane about a vertical axis through O, by deflecting its spin axis from XX to $X_1 X_1$ with an angular difference of θ.

Since the additional work, introduced by external effort is across the plane of rotation, it will be transferred in the same direction. This work will be lost from macro body's matter field as soon as it traverses thickness of the spinning macro body. Usually, thickness of spinning wheel, used in a gyroscope, is very small compared to its diameter. Hence, precession of a gyroscope will stop as soon as the external effort ceases.

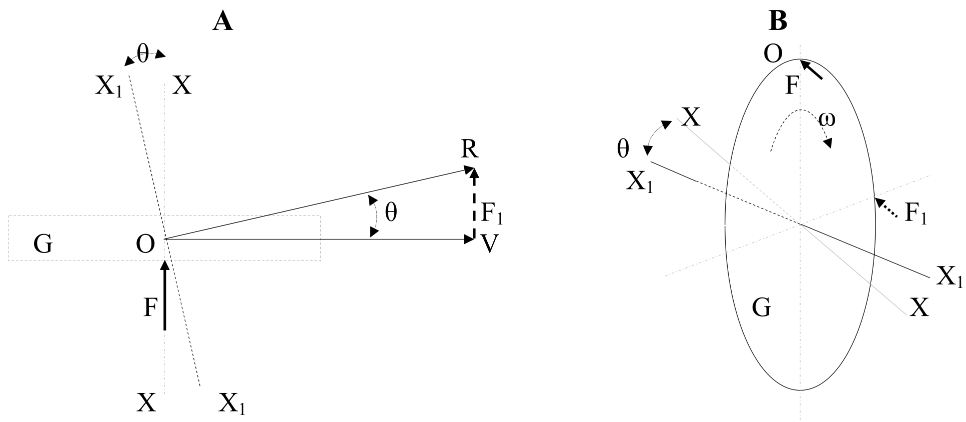

Figure 10

Let an external effort, F, is applied on the spinning macro at a distance, r, from spin axis at point O.

Torque applied by the external effort = F r.

If the macro body was not spinning, this torque would have caused an angular acceleration, α, about centre of mass of the macro body to tilt its axis in vertical plane.

$$\alpha = \frac{Fr}{I}, \qquad \text{where I is the moment of inertia of the macro body.}$$

$$\text{Angular displacement of tilt-motion in unit time} = \alpha\frac{t^2}{2} = \frac{Frt^2}{2I} = \frac{Fr}{2I} \qquad \text{(putting t = one unit)}$$

$$\text{Angular displacement in unit time = Angular speed of tilt-motion} = \frac{Fr}{2I}$$

$$\text{Additional work required for this motion} = k\frac{Fr}{2I}, \text{ where k is the constant of proportion}$$

Additional work, W, about every body-particle of the macro body, causing its spin motion, is proportional to average (tangential) linear speed or displacement in unit time, OV = v, of the body-particle, where, v = r ω. Let 'k' be the constant of proportionality.

$$W = k\,v$$

Additional work, corresponding to external effort F;

RV = F_1, introduced by external effort, F, about the body-particle for its linear displacement in horizontal plane;

$$F_1 = k\frac{Fr}{2I}$$

This additional work acts to turn the spinning macro body about a vertical axis passing through O to angularly displace spin axis of the spinning body from X X to X_1 X_1.

Angular difference between OV and OR, angle θ is angular displacement of the spinning macro body about a vertical axis through O, such that;

$$\text{Tan}\theta = \frac{VR}{OV} = \frac{F_1}{W} = \frac{kFr/2I}{kv} = \frac{Fr}{2Iv}$$

Putting v = r ω, where v is the tangential speed of body-particle in the spinning macro body at the point of application of external effort, r is distance between spin axis and point of application and ω is the angular speed of the spinning macro body.

$$\text{Tan}\theta = \frac{\text{Fr}}{2\text{Iv}} = \frac{\text{Fr}}{2\text{Ir}\omega} = \frac{\text{F}}{2\text{I}\omega} \quad \textbf{(6)}$$

Angular speed of deflection = θ = Rate of precession;

$$\theta = \text{Tan}^{-1}\frac{\text{F}}{2\text{I}\omega} \quad \textbf{(7)}$$

Usually, magnitude of precession rate, θ, is small so that value of (Tan θ) is very small. Value of (Tan θ) is directly proportional to magnitude of external effort and inversely proportional to moment of inertia of the spinning macro body and its spin speed. Increase in spin speed or macro body's moment of inertia increases rigidity of the macro body in space and reduces its precession for certain external effort. In order to take advantage of these factors, spinning macro body of a gyroscope is shaped so that for the same mass, its material is distributed to attain very high moment of inertia and the macro body is spun at very high angular speed. As the spin speed of a macro body reduces, rate of its precession, for the same external effort, increases until at very high values of factor F/2Iω, the rate of precession approaches 90° to topple the macro body in the direction of external effort.

Planetary orbital path:

Current laws on planetary motion are formulated in relative reference frame. Thus, paths of planets are depicted as closed geometrical figures (circular/elliptical) around a central body. These are apparent orbital paths as may be observed by an observer placed at the centre of the static central body [5]. Relative reference frame may be used only to determine relative positions of member-bodies of a planetary system. They cannot give true parameters of the member-bodies or their real paths in space. Real planetary orbital paths are wavy in space, constituted by curved paths alternately on either sides of a median centre circular path around galactic centre. True parameters of member-bodies of a planetary system and their behaviors can be assessed only in absolute reference frame.

Properties of circular paths are exhibited by planetary orbital paths only at their apsides. At all other points, planetary paths are curved on either sides and crosses median path to form wavy shape.

Conclusion:

Outward component of instantaneous motion of a body, moving in circular path, is attributed to the imaginary 'centrifugal force'. Action of an external effort on a macro body does not cease on terminating the effort. Identical inertial delay is applicable after termination of an effort as during initial period of action of the effort. Direction of instantaneous linear motion of a body, moving in circular path, is deflected outward from the tangent to the circular path. Radial size of a stable galaxy is determined its spin speed.

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