

MOTION IN CIRCULAR PATH

(According to “Hypothesis on MATTER”)

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Abstract: All inertial motions are in straight lines. Rotating motion or motion of a body in curved path is the result of straight-line motions of its particles in different directions at differing linear speeds. A body, moving in a circular path, is under a constant centripetal (central) force. The body, under motion in circular path, simultaneously has motions in two linear directions. Direction of one of the linear motions is towards the centre of the circular path, in the direction of the centripetal force. Direction of the other linear motion is deflected outward by an angle from the tangent to the circular path. Outward component of this linear motion gives rise to the assumption of centrifugal force. In cases of motion in a circular path, the centripetal motion not only compensates the outward component of body’s linear motion but also change the direction of body’s linear motion by an equal magnitude. Work, invested into a body, continues to act on the body even after the cessation of force, until the work is stabilized and the body attains a steady state. Ignoring this fact caused the assumption that the direction of instantaneous linear motion of a body, moving in circular path, is tangential to its path.

Keywords: Force, Work, Inertia, Motion, Centrifugal force, Centripetal force, Hypothesis on MATTER.

Introduction:

“Hypothesis on MATTER” describes an alternative concept. In it: Whole matter is contained in the postulated quanta of matter. Matter content of a body and the energy about the body are distinctly separate. Matter content of a body is the total sum of three-dimensional matter in it. Energy is the strain developed due to ‘distortions’ in the natural latticework arrangements of quanta of matter in and about a body. Matter content and energy content of a body cause and support each other for their existence and stability. They are not convertible into each other. ‘2D energy fields’, two dimensional latticework structures by 1D 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 the body-dimensions contain sufficient distortions to sustain the integrity and stability of a (macro) body in its current state. This part of 2D energy fields is the ‘matter field’ of the macro body. Distortions in the matter field are the ‘work’, existing in the macro body and it determines the state of the body. All apparent interactions between matter particles take place through the universal medium of 2D energy fields. This avoids the assumption of ‘actions at a distance’.

2D energy fields fill the entire space. It is aether-like universal medium, but with definite structure and properties. Transfer of distortions in the 2D energy fields transfers the work. Strain, produced by distortions (work) in the 2D energy field is the energy. Due to compressibility, caused by the latticework structure of 2D energy fields, transfer of distortions in them is subject to time delay and an action, subjected to time delay, is an inertial action. Rate of transfer of work is the force (or power). All forces are originated from the gravitational actions of 2D energy fields, on disturbances (3D matter particles) in them. It is an inherent property of 2D energy fields to strive to be isotropic and homogeneous. Distortions in any part of 2D energy fields tend to spread-out. Distortions are transferred from higher distortion-density region to lower distortion-density region. During the transfer of distortions, any matter particles in the region are also carried along with the distortions to cause motion of matter bodies in space. Matter is incapable of any actions or movements on its own. It is the inertial actions of the 2D energy fields about a matter body, which move the matter body. Therefore, the inertia (attributed to matter bodies) is an inherent property of 2D energy fields, in and about a matter body (matter field of the body). Inertial delay is required for the changes in the 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.

Motion in curved path:

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

Motions of bodies, in curved paths, are combinations of two or more straight-line motions. Actions of external forces on a body are to change the magnitude and/or direction of their motion or curve their paths of motion. External forces, causing the curvature of the path, act at an angle to the straight line of motion of the body. For motion in a circular path, the external force, acting on the body, has to be of constant magnitude and perpendicular to body’s instantaneous straight-line path. For the following explanation, motion of a 3D macro body in circular path is used. Principle of motion in any curved path is similar with small differences related to the relative direction and duration of application or changes in the magnitude of the external force.

At any instant, a moving macro body (in its stable state) travels in a straight line. To move in a circular path, a linearly moving macro body requires the action of an external force (called centripetal force) towards the centre of the curve. The macro body accelerates towards the centre of curvature of the path. Displacements of the body, in linear direction, 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. During the macro body’s displacement towards the centre of curvature, certain part of work (producing the motion in straight-line path) is lost from the body’s matter field and certain part of work (producing its motion towards the centre of curvature) is stored within its matter field. These distortions together form the resultant distortions in the matter field, to produce macro body’s motion in the resultant direction of both the external forces. Instantaneous changes in the resultant direction of body’s motion cause the curvature of its path.

A body, on which the centripetal force ceases to act, appears to move in tangential direction to its curved path. From this observation, it is simply assumed (without any logical reason) that the body's instantaneous linear motion is always tangential to its curved path. Since the length of a segment of a curve is the product of angle subtended at the centre and its radius, instantaneous tangential linear speed of a body, moving in circular path, is assumed to be the product of angular speed (in radians) and the radius of the 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 bodies moving in curved paths of reasonably large radius, calculations based on these assumptions do not make observable differences. However, if the body involved, is very large with reasonably large radius of curvature of its path or the body is very small with small radius of curvature of its path, considerable discrepancy will appear in the result. When the inertial actions about the body are taken into consideration, it can be seen that the direction of instantaneous linear motion of a body, moving in a curved path, is deflected outwards from the tangent to the curved path. Magnitude of the deflection is proportional to the body's centripetal acceleration (and the curvature of the path).

Consider a small macro body moving at a (reasonably high) constant speed along a straight line. Let a small external force act uniformly on the body in perpendicular direction to its motion. Distortions in the matter field, introduced by the external force, change the direction of body's motion. Inertial delay is applicable to this action also. If the perpendicular force (to the instantaneous linear motion of the body) is continuous and is of constant magnitude, direction of motion of the body changes at a constant rate.

In figure 1, circles, I & II, represent a body moving at a constant linear speed along the central line, XX, in the direction of the arrow. Magnitude of matter field distortions, producing body's linear motion, remains constant and moves the body at a constant linear speed. The vertical arrow represents continuous external force acting on the body, perpendicular to body's direction of motion.

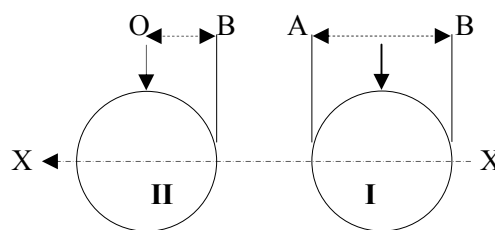


Figure 1

Additional distortions are introduced into the matter field of the body by the perpendicular force in its direction of action. As the body moves forward, the 2D energy fields in the forward part of the body (in the direction of force) receive new perpendicular distortions, which are augmented by the continuous action of the perpendicular force, as the body progresses in its resultant path. Under constant action of the perpendicular force, whole of the body's matter field within the segment AB (as shown in figure 1-I) receives perpendicular distortions. Due to body's forward motion, 2D energy fields to the rear of the body go out of body's matter field. Perpendicular distortions contained in this part of the body's matter field are lost into space. 2D energy fields at the rear-most part of the matter field have the highest perpendicular distortion-density and the foremost part of the matter field has the least perpendicular distortion-density. Since the linear speed of the body is constant, average perpendicular distortion-density in the matter field remains constant and changes the direction of body's motion at a constant rate. Initially, the body attains its steady state corresponding to the external force and steady linear motion only after the inertial delay. During the inertial delay, the body accelerates towards its new steady state.

If the magnitude or direction of the external force is modified, the body will accelerate or decelerate and reach its steady state only after the inertial delay. As long as the size and matter density of the body is not varied, duration of inertial delay is constant for a macro body. Even if the external force, acting in perpendicular direction to the body's linear motion is removed, action of the (unused part of the) distortions due to the perpendicular force will continue on the body as long as the perpendicular distortions, introduced by the external force, are present in the matter field of the body. After the termination of the external force and its full utilization, in the body to attain a steady state, whole of the perpendicular distortions introduced by the external force is lost from the matter field, as the body moves away from the 2D energy fields, which contain the distortions due to the (now) ceased perpendicular force.

Figure 1-II shows the linearly moving body at the instant, when the perpendicular force is terminated. No new perpendicular distortions are introduced into the matter field of the body. Perpendicular distortions, present in its matter field, remain with the body until they are lost into space due to body's

forward displacement. At the instant of severance of the perpendicular force, the body contains whole of the perpendicular distortions and after the inertial delay, it is left with only those parts of perpendicular distortions, contributing to body's steady state by amalgamating with the linear distortions to form the present resultant distortions in the matter field of the body. During the inertial delay, body's matter field loses part of the perpendicular distortions, contributing to body's acceleration. Even those perpendicular distortions, contributing to the steady state motion (in perpendicular direction) of the body are lost from its matter field, by the time it traverses a distance equal the length of the body. Average magnitude of distortions, present in the matter field during the inertial delay, can be taken roughly (more accurate value is required only in cases of very large bodies, as in the case of 'motion under central force') as half of the total perpendicular distortions, available during the action of the force. Hence, the displacement of the body during the inertial delay due to (now-removed) external force is reduced to half the magnitude of displacement produced by continuous action of the external force in unit time.

According to present theories, in the calculations involving motion of a body in circular path, effects of inertia of the body after the termination of the external force are not taken into consideration. It is assumed that as soon as the external force is terminated, all effects due to the force also cease. This belief is based on observation of a particle detached from the rim of a rotating wheel (or similar phenomena) that the particle appears to move in the direction tangential to the curve. This is not the true direction of particle's motion. It takes certain time for a force to take effect on a body. Hence, it is only logical to think that the termination of a force also takes similar time delay to take effect on the body.

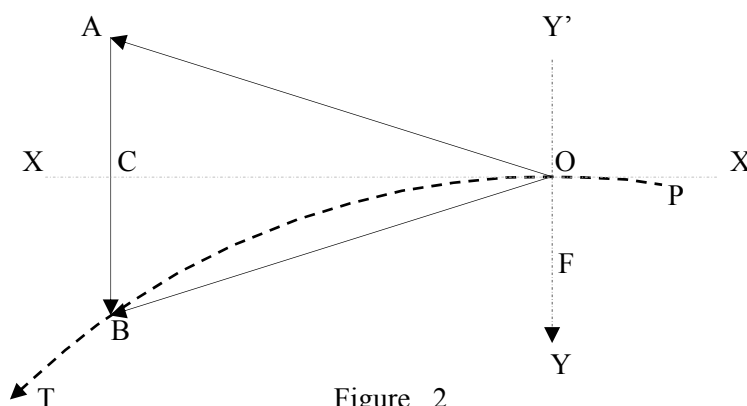


Figure 2

Figure 2 shows the motion of a very small body along the circular path OT. Work is invested into (matter field of) the body by the continuous action of the centripetal force (along the arrow OY – shown as a pull-force) towards the centre of curvature of the path. The body, at the instant of consideration, is at O. Y'Y is the direction of centripetal acceleration. Due to curvature of the path, direction of centripetal force with respect to the body changes continuously. F is the centripetal force, m is the mass of the body, representing its matter content and a is the body's centripetal acceleration.

$$a = F \div m$$

Displacement of the body in perpendicular direction in unit time due to centripetal acceleration,

$$AB = a \div 2 \quad (\text{putting } t=1 \text{ in equation; displacement} = at^2/2)$$

At the end of unit time, the body is displaced to a position, B, which is the resultant of its linear motion and the displacement due to centripetal force in unit time.

Let OA represent body's linear velocity, v, at O.

$$OA = v \text{ units} \quad \text{and} \quad AB = a/2 \text{ units}$$

As long as the linear speed of a body and its centripetal acceleration remain constant, the body moves in a circular path. It is in a steady state of motion. To move in a circular path, body's instantaneous linear speeds at all points on the path remain the same.

$$\therefore OB = OA$$

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

Since $AB = a/2$, $AC = BC = a/4$

(1)

The body continues to move in a circular path.

Remove the centripetal force when the body is at O:

During the inertial delay, after the termination of the centripetal force, distortions already introduced into matter field of the body (at the instant of termination of the centripetal force) continue to accelerate the body in the same direction. Acceleration of original magnitude is gradually reduced until all the acceleration components of the distortions, introduced by the (now-removed) centripetal force are lost from the matter field. As the magnitude of acceleration component of distortions at the end of acceleration is zero, 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 force.

Let the magnitude of perpendicular distortions in the matter field, in steady state = W

Magnitude of distortions, in the matter field at the instant of termination of external force = W

Magnitude of perpendicular distortions held by the matter field at the end of inertial delay = 0

Average magnitude of perpendicular distortions during inertial delay = W/2

Centripetal acceleration is proportional to the perpendicular distortions in the matter field.

Average centripetal acceleration during inertial delay = $a/2$

Let the inertial delay = unit time

Displacement of the body, due to reduced centripetal acceleration, during inertial delay = $a/4$

The body attains its steady state of motion on completion of acceleration and in the mean time; the body is displaced by a distance, $a/4$, to C on the tangent through O. At C, the body has no more action on it, to curve its path and it will continue to move in a steady state of linear motion along OC, which is the tangent to the curve at O. This is the reason, why a body or a particle released from centripetal force moves in tangential direction to its curved path. Original direction of body's instantaneous linear motion is along OA, which is deflected outward from the tangent. Angular deflection of direction of the instantaneous linear motion creates an illusion that the body is trying to move away from centre of curvature of the path. This apparent attempt is assigned to the imaginary centrifugal force. Imaginary forces cannot act on a real body.

Consider a small body O, moving in circular path around a central point, to which the body is attached by a rigid link or string (as shown in Figure 3). At any instant, natural motion of the body is in a straight line, slightly deflected outward from the tangent on its path. Action of the centripetal force displaces the body sideways during its travel, to curve its path.

Figure 3 (not to scale) represents displacements of the body in unit time. Figure 3-I shows the body at point O in its circular path. XX is the tangent to circular path at O. OA is body's instantaneous linear speed. OY is the displacement of the body due to centripetal acceleration in unit time.

Resolve body's linear motion OA into two parts. One part, OC, is along the tangent and the other, CA, is perpendicular to the tangent. The component, CA, acts perpendicular to the tangent and tries to extend the rigid link's length. Since the link is assumed to be rigid, the force cannot increase its length. Attempt to increase the 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 body's linear motion. The inter-particle field force that maintains the rigidity of the link resists attempt by the linear motion to extend its length. This resistance acts as a reactive force on the body, O, to pull it inward towards the centre of the path. Since the production of the reactive force involves structural changes in the matter field of the link, it is a real force. This acts as an external force on the body to curve its path.

Resolve the result (motion produced) of the centripetal force, OY, 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 body. The other component, FY, acting perpendicular to the linear motion, displaces the body to its new position, B, on the curved path.

path at O. Resultant motion of the particle, along its circular path, is shown by the arrow, OB.

$$AB = OE = \frac{a}{2}, \quad OA = OB = v, \quad \angle AOB = \theta, \quad \angle AOE = \alpha$$

By parallelogram law of forces,

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

$$v^2 = v^2 + \left(\frac{a}{2}\right)^2 + 2v \frac{a}{2} \cos \alpha, \quad \left(\frac{a}{2}\right)^2 = -2v \frac{a}{2} \cos \alpha, \quad a = -4v \cos \alpha$$

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

Substituting the value of α ,

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

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

$$\frac{\theta}{2} = 90 - \cos^{-1} \frac{a}{4v} \text{ degrees} \quad (3.8/2)$$

Let the 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, through the point, when its unity to the wheel is broken. At the instant of detachment, the particle is also under the centripetal force and this force has been providing particle's radial acceleration. When the unity of the particle with the body is lost, centripetal force is no more present, on the 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 one unit of time, displacement of the 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 the tangential line during the inertial delay and by the centripetal force that existed at the instant of detachment. Curved dashed arrow OC, in figure 4, shows the approximate path of the particle after it broke away from the rotating wheel until it achieve a steady state of motion along the tangent to the path at O. If the particle were originally moving along the tangent to the rim, you would see the particle flying away from the rim along a path that is deflected inwardly from the tangent.

Generally, the component of linear motion of the particle (deflected outward from the tangent), perpendicular to the tangent is attributed to the imaginary centrifugal force. (In this case, the other component, the linear motion is assumed to be in tangential direction). Displacement due to centripetal force not only compensates for the part of displacement attributed to the centrifugal force but it also displaces the particle beyond the tangent to curve particle's path. Thus, the magnitude of centripetal force appears to be twice that of the imaginary centrifugal force. Uneven distribution of perpendicular distortions in the matter field of the body, moving in circular path, causes a torque on the body, in addition to the curvature of body's path. This leads towards the phenomena of planetary spin in multi-body systems. [2].

Conclusion:

Outward component of instantaneous motion of a body, moving in circular path, is attributed to the imaginary centrifugal force. Action of an external force on a body does not cease on terminating the external force. Identical inertial delay is applicable after the termination of a force, as is in the case, during the initial period of action of the force. Direction of instantaneous linear motion of a body, moving in circular path, is deflected outward from the tangent to the circular path.

References:

[1] Nainan K. Varghese, *Hypothesis on MATTER* (second edition), (2008).

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[2] Nainan. K. Varghese, ARTICLES, <http://wbabin.net/papers.htm#Varghese>

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