



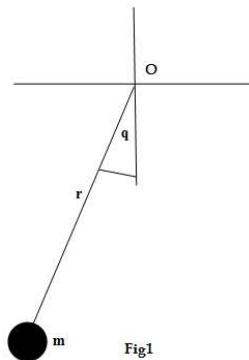
undefined

Miura - parametric acceleration

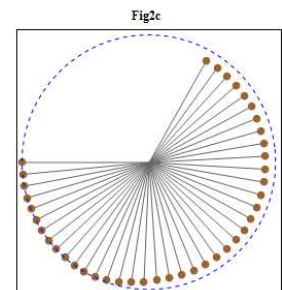
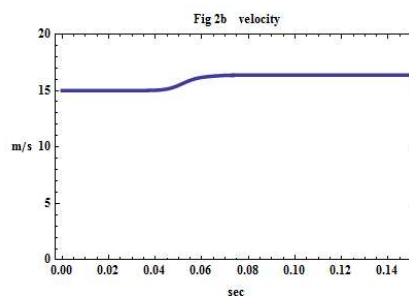
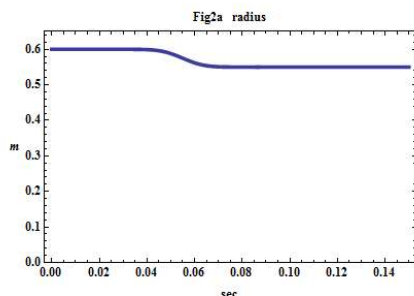
For some Miura's parametric acceleration might possibly seem a bit surprising as it refers to obtaining more speed for the clubhead by exerting a force on it, not tangentially, in line with the trajectory, but rather perpendicular to it. This does not quite fit with our intuitive knowledge of how objects behave when a force is exerted on it to obtain motion. The analysis below gives I hope a simple but clear explanation of how Miura's parametric acceleration can lead to more velocity by a force acting perpendicular to the trajectory.

The use of the adjective 'parametric' was chosen by Miura in line with its use in science when referring to parametric oscillators, where a parameter is used to sustain oscillations, e.g., a child swinging a playground swing or a varactor parametric oscillator. In Miura's parametric acceleration one has a parameter, a varying swing radius, being used to induce acceleration.

Miura has become the flavour of the month. Therefore it is useful to look a bit into the basic physics behind parametric acceleration. We strip things to absolute bare bones and look at the forces acting on a simple point mass rotating around a center and experiencing, for a short while, a shortening of its swing radius. The mass is connected to the center with a cord and there is assumed some mechanism to pull the cord through the center point, to reduce the radius.

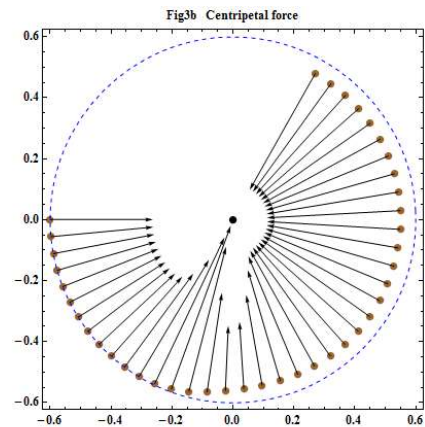
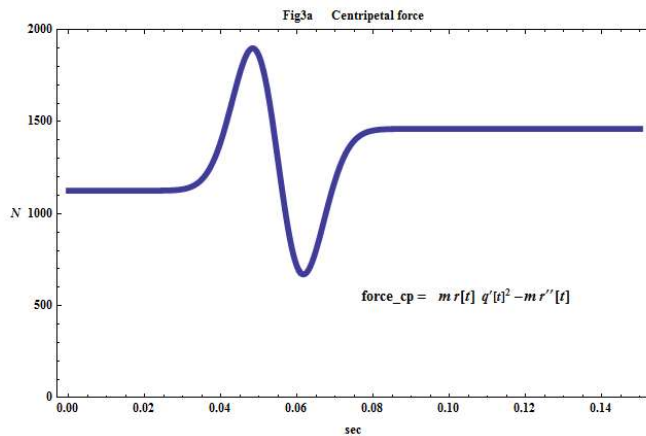


We assume the point mass to whirl around with constant angular velocity and being supported by a frictionless horizontal surface. In Fig2 is depicted respectively radius, tangential velocity and 2D motion of the mass having initially a constant angular velocity. A short duration shortening of the swing radius is operated by pulling the cord through the hole in the center. Notice the ensuing increase in velocity of the mass m , Fig2b, and its 2D motion in Fig2c.



Now let's look at the forces acting on the mass, especially during the time interval when the radius shortens. Figs 3a and 3b show respectively the magnitude of the centripetal force and the centripetal force vector. Someone might be puzzled a bit. How come mandrin that there is an increase in velocity yet the force acting on the mass, during the phase that the radius shortens, seems to remain going through the center, as can be seen in Fig3b. Therefore how can the mass accelerate tangentially and hence, increase its tangential velocity? One can

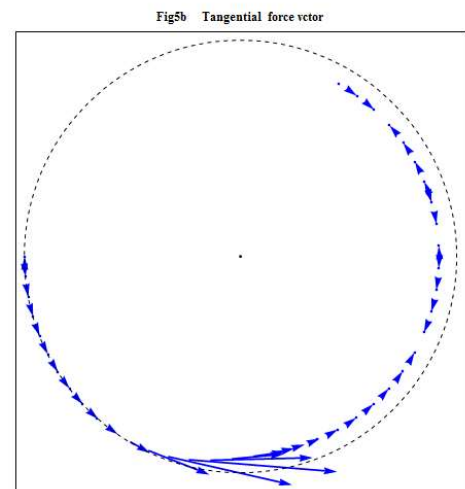
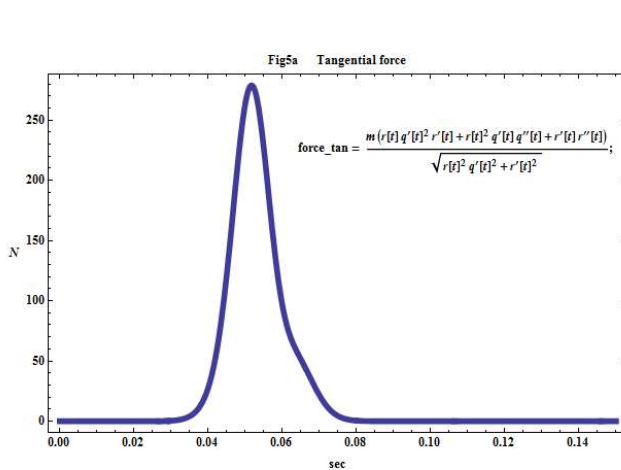
Fig3b. Therefore now can the mass accelerate tangentially and hence increase its tangential velocity: One can answer correctly and succinctly that centripetal force is doing positive work hence injecting equivalent kinetic energy but that does not connect quite with our intuition.



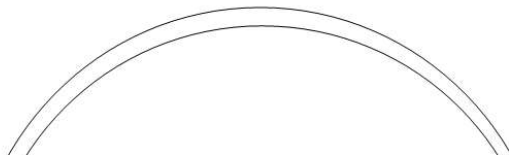
Figs 4a and 4b tries to illustrate this question. We are accustomed to think of a force acting along the line of motion of the mass. We push or pull on a object and it accelerates in line with the force applied. However if we apply a force sideways on a moving object we don't expect it to accelerate and hence increase its velocity in the direction of its existing motion, Fig 4b. Yet this seemingly seems to occur with the rotating mass. To solve this apparent contradiction we have to look a bit closer at what is going on.



It is true that the centripetal force remains going perfectly through the center when the swing radius shortens. But this has to be as the cord can't transmit a lateral force. Hence it appears that the force remains perpendicular to the motion of the mass. However is this really true? Not quite as the motion of the mass, during the small time interval its radius is shortened, is not perfectly perpendicular to the direction of the centripetal force. As a consequence there is effectively a force component developed tangentially to the actual trajectory of the mass. It takes some subtle vector operations but the results are shown in Fig5a and Fig5b.



When a mass circles with constant angular velocity around a fixed center at any time the centripetal force is perpendicular to the path of the mass. There is hence no tangential force acting on the mass, Fig 6a. When there is a shortening of the swing radius there is a transition from the old to the new shorter swing radius. During this transition the physical center of rotation and the actual instantaneous center of rotation don't coincide. The angle between the centripetal force and the trajectory is not anymore a perfect 90 degrees and a lateral component is created tangentially to the trajectory as illustrated in Fig6b/c. A faster transition results in greater tangential force.



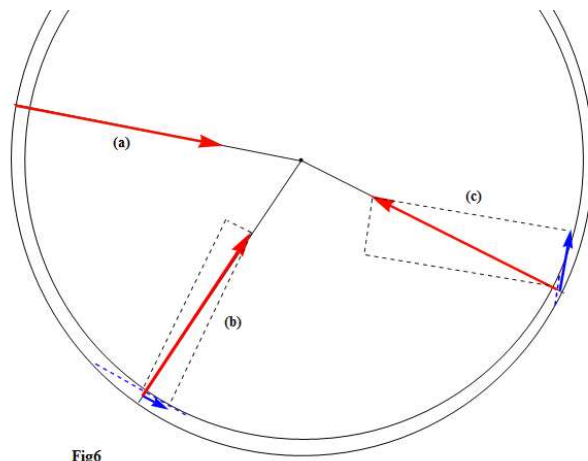


Fig6

At first it might appear a bit strange to obtain greater velocity for an object by having a perpendicular force exerted on it. But once we realize that there is also a tangential force component created it might be more easily accepted. The tangential force, acting on the mass, results from there being an angle between trajectory and centripetal force, deviating from 90 degrees, during the shortening process of the swing radius. Hence without resorting to any mathematics it can also be understood that if this transition in swing radius occurs faster than we have also a greater resulting tangential force as there is a larger angle, deviating from 90 degrees, between trajectory and centripetal force vector.

The analysis of the parametric acceleration in a golf swing is more complicated as it involves not simply a point mass but several linked segments. However the underlying physics remains the same. For instance it might be understood from above why parametric acceleration is only significant when the centripetal force is large, hence only close to impact, and also why the upward motion of the center of mass of the golfer has to be very brisk to have some effect, see Fig6b/c. However there is no magical untapped force being discovered. Golfers have been using it without any idea of parametric acceleration. Its use in a golf swing is a minor clubhead speed contributor when executed properly.

Reference

Miura, K. (2001)
Parametric acceleration - the effect of inward pull of the golf club at impact stage.
Sports Engineering 4(2), 75-83

mandrin