

# Correcting Misconceptions Regarding Foucault Pendulum Precession

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## Abstract

This work serves to correct three errors that appear in explanations of the precession of the Foucault Pendulum. The first erroneous claim is that the plane of oscillation of the pendulum remains fixed with respect to inertial space. The second claim is that the plane of oscillation rotates in the clockwise direction. The third claim is that the precession of the pendulum is caused by the Coriolis Force. A previous paper showed that the plane of the pendulum's oscillation rotates in the counterclockwise direction, thereby disproving the first two claims. If the pendulum is perfectly decoupled from its mounting fixture in the axial or vertical direction and has zero spin rate about the vertical axis, it will still appear to precess even with zero oscillation amplitude. Without pendulum oscillation, there is zero Coriolis Force, which proves that the Coriolis force is not required for the precession phenomenon. Since an Earth fixed observer spins about the vertical axis due to the angular rate of the Earth, the pendulum's vertical axis appears to rotate or precess in the clockwise direction.

Keywords: Foucault Pendulum, Absolute rotation angle, Precession rate, Attitude kinematics, Solid angle

## 1. Analysis

Explanations of the precession of the Foucault Pendulum (Sommeria, 2017) often contain misconceptions because the physics is not easily understood. The plane of oscillation is not fixed in inertial space, as is often reported. The Coriolis Force is often reported as the cause of the pendulum's precession, yet non-oscillation pendulums having zero Coriolis Force can still precess similar to an oscillating pendulum. This work serves to correct some misunderstandings regarding the Foucault Pendulum that are being propagated via internet references and infecting AI (artificial intelligence) summaries that are produced by internet search engines.

The Foucault Pendulum can be treated as a vertical axis located at a particular latitude on the Earth's surface. Previous work (Patera, 2020) showed that the general attitude transformation of such an axis consists of three terms; 1} a slewing transformation along a geocentric arc linking the initial orientation of the axis to its final orientation, 2} a rotational transformation about the axis equal to the solid angle bounded by the actual trajectory of the axis and the great circle arc linking the initial and final orientations, 3) a rotational transformation about the axis equal to the time integral of the Earth's angular rate projected along the vertical axis. An observer stationed on the Earth rotates based on only the last two terms, since the slewing motion is not directly observable. The pendulum itself rotates about the vertical axis based on the second or solid angle term, since it is decoupled from the Earth's angular rate along the vertical axis.

The rotation about the pendulum's axis due to the solid angle term was computed for any Earth rotation angle in a previous work (Patera, 2021) and (Patera, 2022). If one considers a complete rotation of the Earth, the solid angle term involves the spherical cap north of the pendulum's latitude, which is given by eq. (1), where  $\Omega$  is the solid angle and  $\theta$  is the latitude.

$$\Omega = 2\pi [1 - \sin(\theta)] \quad (1)$$

Earlier work (Patera, 2020) showed that the pendulum rotates in the counterclockwise direction by an angle equal to the solid angle given in eq. (1). A vertical axis fixed to the Earth and parallel to a

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stationary pendulum's axis, also rotates by an angle given by eq. (1). However, the component of the Earth's spin rate along the vertical axis causes an additional rotation along the axis of  $2\pi$  times sine of the latitude. In fact, after one complete rotation of the Earth, the pendulum's mounting fixture rotates in the vertical direction by the sum of the solid angle rotation of eq. (1) and the contribution of the Earth's angular rate as shown in eq. (2). Thus, every vertical axis in the Northern Hemisphere rotates by  $2\pi$  or 360 degrees. after one complete rotation of the Earth regardless of its latitude.

$$\Omega = 2\pi [1 - \sin(\theta)] + 2\pi \sin(\theta) = 2\pi \quad (2)$$

Since an Earth fixed observer rotates more than the pendulum in the counterclockwise direction, the pendulum appears to precess in the clockwise direction.

## 2. Precession of a non-oscillating Foucault Pendulum

A non-oscillating Foucault Pendulum that is perfectly decoupled from its mounting fixture along the vertical axis and has no torques applied in the axial direction, will maintain a constant axial rotation rate. If such a pendulum is setup in this manner, its axial rotation rate is given by the projection of the Earth's spin rate along the axis. This is due to the fact that every object fixed to the Earth at latitude,  $\theta$ , has the ambient spin rate in the vertical direction given by eq. (3), where  $\omega$  is the Earth's angular rate and  $\lambda$  is the vertical spin rate.

$$\lambda = \omega \sin(\theta) \quad (3)$$

Since this pendulum has the same axial rotation rate as an Earth fixed observer, the pendulum will not appear to precess. However, if the non-oscillating pendulum is initialized with zero axial angular rate, it will appear to precess exactly like an oscillating pendulum. An oscillating pendulum ensures that the axial angular rate of the pendulum remains zero. Therefore, a non-oscillating pendulum precesses just like an oscillating pendulum, if it is initialized with zero axial angular rate.

Since the non-oscillating Foucault Pendulum has zero velocity with respect to the Earth, it has zero Coriolis Force acting on it. Therefore, one can conclude that the Coriolis Force is not responsible for the precessional motion of a Foucault Pendulum. In fact, the precession of the Foucault Pendulum was shown to be the result of attitude kinematics and not attitude dynamics (Patera, 2021). This disproves the third claim that the motion of the Foucault Pendulum is caused by the Coriolis Force.

## 3. Conclusion

Three misconceptions regarding the precession of the Foucault Pendulum were disproved in this work. The first two claims were disproved simply by referencing previous work. The third claim regarding the Coriolis Force as being the cause of the precession phenomenon was disproved by considering a non-oscillation pendulum. Since a properly initialized non-oscillating pendulum has zero Coriolis Force, yet precesses exactly like an oscillating pendulum, the Coriolis Force cannot be the fundamental cause of the precession.

## References

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