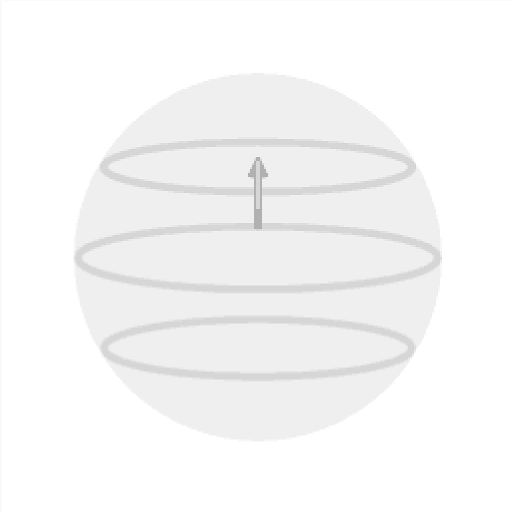
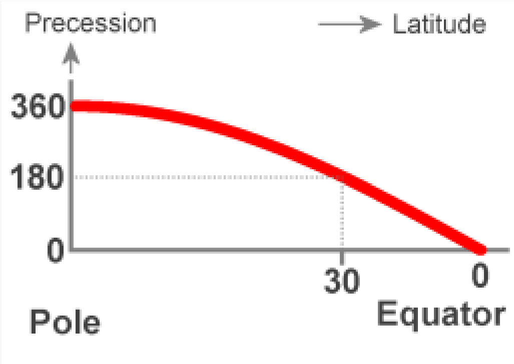
THE FOUCAULT PENDULUM



Picture 1. Animation
A Foucault pendulum located at 30 degrees latitude takes two sidereal days to complete a precession cycle.

Stereographic animation
(Switches to other page.)



Picture 2. Diagram
The precession with respect to the Earth's surface in degrees per sidereal day.

A Foucault pendulum located at the latitude of Paris takes about 32 hours to complete a precession cycle. This means that after one sidereal day, when the Earth has returned to its orientation of one day before, the pendulum has precessed three quarters of a cycle. If it has started in north-south direction, it is swinging east-west when the Earth has returned to the orientation of one day before.

Animation 1 represents another example, the case of a Foucault pendulum located at 30 degrees latitude. One can recognize that the plane of swing takes two sidereal days to precess clockwise with respect to the surface it is suspended above. At the equator the pendulum keeps swinging in the same direction relative to the surface it is suspended above. Diagram 2 depicts that from the poles to the equator there is a smooth transition.

The challenge is to explain the behavior of a Foucault pendulum that is not located on either the poles or the equator. Many discussions of the Foucault pendulum merely rephrase the observation. For instance, Hart, Miller and Mills point out that "the angular velocity of the plane of the pendulum is simply the projection of the Earth's angular velocity onto a line joining the center of the Earth and the point of suspension of the pendulum".[1] That's an empty statement; it just restates the already known.

A satisfactory explanation of the motion pattern of the latitudinal Foucault pendulum has been given by meteorologists[2]. The fact that meteorologists have made a crucial contribution is not as surprising as it seems. Air mass, the object of study in meteorology, is pretty much prevented from moving in vertical direction, but there is hardly any restraint to motion parallel to the local Earth surface. Likewise, the pendulum bob has no freedom in vertical direction, but it is unconstrained in the directions parallel to the Earth's surface. Whenever air mass has a velocity relative to the Earth there is an effect that arises from the overall *Earth rotation*. Likewise, the fact that the swinging pendulum is circumnavigating the Earth's axis affects the motion of the pendulum.

I will call a Foucault pendulum located on one of the poles a *polar Foucault pendulum* and a Foucault pendulum located somewhere on the equator an *equatorial Foucault pendulum*. A Foucault pendulum located at any latitude between the poles and the equator I will call a *latitudinal Foucault pendulum*.

The motion pattern of the Foucault pendulum involves two oscillations, at different scales of magnitude. At the small scale there is the swing of the pendulum, which I will refer to as 'the vibration'. At the large scale there is the overall rotation of the Earth around its axis. The vibration participates in the overall rotation and is affected by it. Due to the large difference in period of oscillation the effect is very small during each separate swing. It appears to be negligable, but it's actually significant because the effect is *cumulative*. My purpose is to show why the effect is cumulative.

The Wheatstone-Foucault device

Picture 3. Image
Wheatstone's design that displays the same effect as the Foucault pendulum.

In 1851 a paper by Charles Wheatstone was read to the Royal Society in which Wheatstone described the device that is shown in Image 3. A transcript of the paper by Wheatstone is available at wikisource

The helical spring acts as a heavy string; when plucked, it vibrates. The circular platform can rotate around a vertical axis. I will refer to this axis as the central axis.

The Wheatstone pendulum

Picture 4. Image
Version of Wheatstone's device that underlines the similarity with the Foucault pendulum.

Picture 5. Image
A Wheatstone pendulum setup with the attachment points aligned with the central axis of rotation.

I will discuss the physics of the Foucault pendulum by drawing parallels with Wheatstone's device. The features that the Foucault pendulum and the Wheatstone-Foucault device have in common are the features that matter for understanding the physics taking place.

To underline the similarity with the Foucault pendulum, I will discuss a slightly different version of the Wheatstone-Foucault device. I refer to the device depicted in image 4 as "the Wheatstone pendulum". The small sphere corresponds to the bob of the Foucault pendulum, the force exerted by the inside spring corresponds to the gravitational force that is being exerted on the bob, and the force exerted by the outside spring corresponds to the force