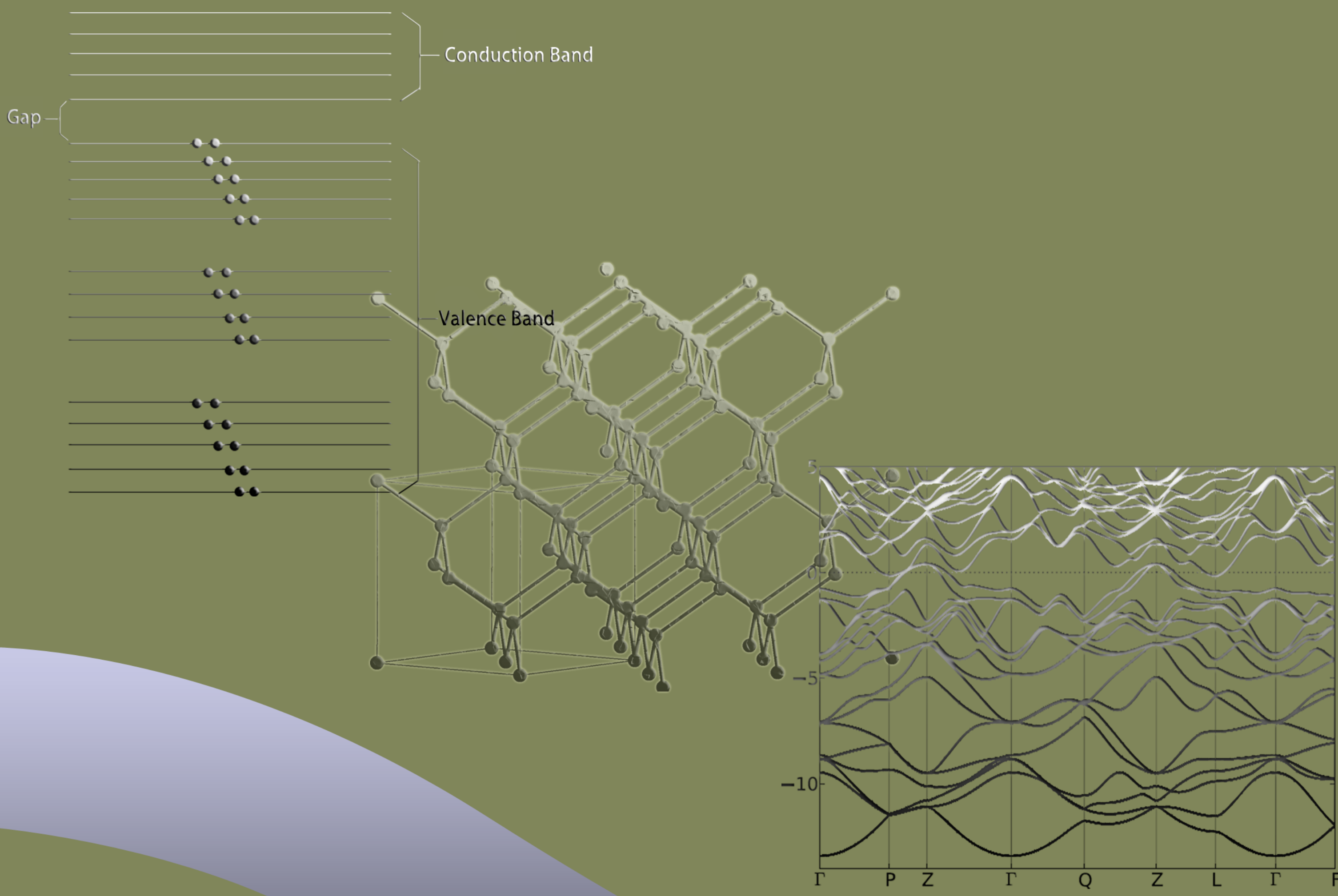
Queen Mary, University of London

School of Physics and Astronomy

About Precession



When we are talking about rotation, we can imagine an virtual axis around which the object is rotating. Furthermore, adding an arrow to that virtual axis will help us define the direction of the rotation. Why do we need to define the virtual rotation axis and the arrow? Imagine observing a rotating object in any given coordinate, if we look at the rotation from above the object, we say it is rotating anticlockwise, however another guy looking at the rotation from below it will definitely give the opposite answer - clockwise. So describing rotation only using the notation of clockwise or

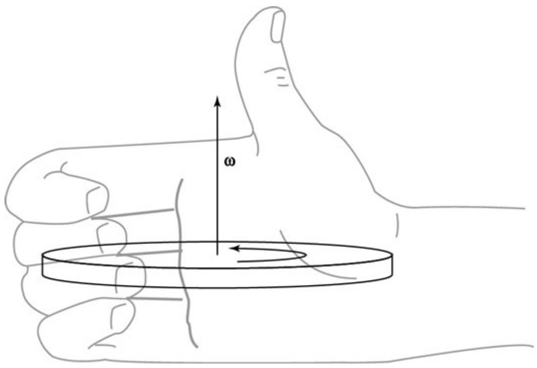


Figure 1. Illustration of right-hand rule for determining the direction of angular velocity.

anticlockwise does make things ambiguous sometime. And that's just where the angular velocity vector comes to help. The definition of angular velocity is somehow like this: the magnitude is just the magnitude of the angular velocity ω, and the direction is given following the right-hand rule, which is shown in Fig. 1.

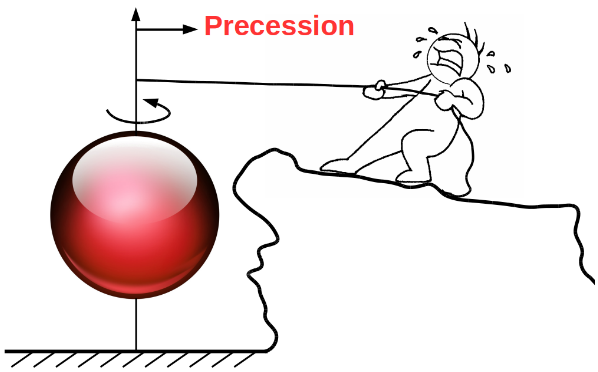


Figure 2. Illustration for precession. However what is shown here is not the precession in real case, only providing an idea about where the precession comes from. Detailed discussion can be found in the context.

Keeping the definition of angular velocity vector in mind, we can then easily imagine the notation of precession, which basically concerns about the direction changing of the rotation. Since we already know that rotation direction defines the direction of its corresponding angular velocity vector, the precession actually describes the direction changing of the angular velocity vector corresponding to specific rotation. Fig. 2. gives the direct visualization of what precession actually means and where it comes from. Here it should be noticed that the situation illustrated in Fig. 2. is not exactly what precession means. In the real case, the rotation direction does not stay in a plane as shown in Fig. 2.. It can also can move into and out of the paper plane, thus the real process of precession is actually the circulating of the rotation direction around a 'vertical' axis.

There are many examples in daily life where we can feel the precession. The one that people can easily find the phenomenon of precession in it is tops. Due to the influence of gravity, the rotating top will finally fall to the ground. Thus the rotation changes from its original vertical direction to the final horizontal direction until falling down on the ground, gradually. The gradual changing of the rotation direction is just what precession means. This is a 'small' piece example of precession, here we could have another 'huge' precession system, which is just our earth. The on-line material (follow the link here) describes the precession of our earth rotation both intuitively and quantitatively. And the following discussion is just basic summary of that on-line material. The illustration given in

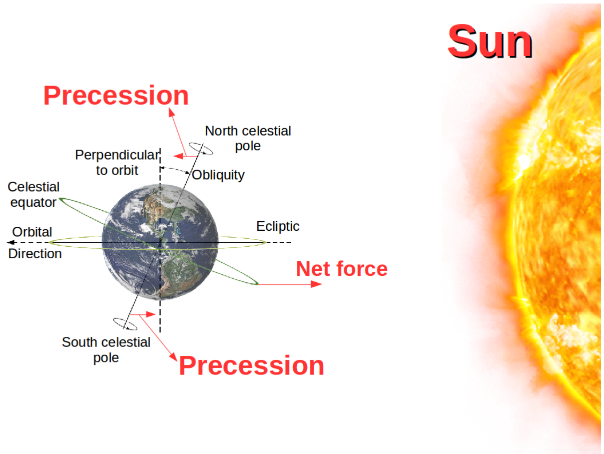


Figure 3. The precession of our earth.

Fig. 3. only considers the interaction between sun and earth, ignoring our near neighbour — Moon. Thus the description here in this article is not exact, providing us only the intuition about where the precession of earth comes from. As we all know, the rotation of earth around itself and around the sun does not coincide with each other in plane. As shown in Fig. 3., that basically means the plane of ecliptic and celestial plane does not coincides with each other. That's one of the reasons for precession of earth rotation. Due to the effect of Coriolis force, the mass distribution of our earth is not uniform, and the mass around the equator is more dense than other area. Thus we can imagine a ring around a uniformly distributed sphere, which is described in Fig. 3. as well and the green ring there is just our imagined ring due to the non-uniform distribution of mass on the earth. This is the second reason contributing to the precession of earth rotation. Moreover, the gravity force between

earth and sun is larger for the area facing the sun than that for area at the far end of the earth (since the distance is larger for the latter case). Then we actually have a net force which is described by a red arrow in Fig. 3.. This is the third reason accounting for the precession of earth rotation. All the three reasons given above are necessary for the precession of earth rotation. For example, if the rotation plane of earth rotating around itself coincides with the ecliptic plane, we will never have the precession since the net force does not create corresponding torque which can change the rotation direction of earth, in that case. Or if we have a uniformly distributed earth rotating around itself, we should have the net force go through the center of earth, which again does not provide the torque needed for changing the rotation direction — thus no precession, either. At last, since our earth is rotating around the sun, the influence of the net force is actually periodic (imagine a 3D analogue to Fig. 3., where the earth rotates into, or out of the paper, or to the right of the sun). Also considering the influence of the moon, the periodicity of precession of earth rotation around itself is around 25,770 years. Detailed about the estimation of this periodicity is given in the above link.