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Methodological Notes

DEMONSTRATIONS WITH MAGNETIZED GYROSCOPES

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1. LARMOR PRECESSION

A symmetrical non-conducting gyroscope, balanced on a Cardan suspension and magnetized along the axis, is used for the demonstration. The gyroscope in the form of a disc (100 mm diameter) mounted on a shaft (15 mm dia.) is made of Plexiglas, so no eddy currents can be produced when it rotates in a magnetic field. A channel is bored through the shaft and a magnetized ferrite rod (8 mm dia.) is placed in it. The gyroscope is set in rotation with the aid of a string wound on the shaft. Shadow projection is used to observe the gyroscope motion.

It is necessary to show first that the gyroscope axis is magnetized. To this end, the non-rotating gyroscope is placed between the poles of an electromagnet and damped oscillations of its shaft about the field direction are observed. The direction of the field is then reversed, and the reversal of the magnetized shaft of the non-rotating gyroscope is observed.

To demonstrate the Larmor precession, the gyroscope is accelerated with the electromagnet turned off, the gyroscope shaft being inclined 20—60° to the field direction. After the electromagnet is turned on, Larmor precession of the gyroscope axis about the field direction is observed. It is shown further that an increase of the field intensity leads to an increase in the angular velocity of the precession, and turning off the field leads to an "inertialess" cessation of the precession. When a field of opposite direction is turned on, the precession likewise sets in "without inertia," but the direction of the angular velocity is reversed. No reversal of the magnetized shaft of the rotating gyroscope is observed when the direction of the field is reversed.

2. ORIENTATION OF MAGNETIZED CONDUCTING GYROSCOPE IN A MAGNETIC FIELD

The demonstration is made with a symmetrical gyroscope in the form of a duraluminum disc (100 mm dia.) mounted on a magnetized steel shaft. When such a rotating gyroscope is placed in a magnetic field, the motion of its axis is determined not only by the interaction between its constant magnetic moment $\mathbf{P}_{m_0}$ and the external magnetic field (the Larmor precession), but also by the interaction between the field and the magnetic moment of the eddy currents[1], which leads to an orientation of the gyroscope axis along the field[2,3].

The latter effect can be relatively easily demonstrated and consists in the following[4]. When the magnetic field is turned on, the axis of the conducting non-magnetic gyroscope turns along the shortest path in the direction of the field. The angular momentum vector N of the gyroscope can assume one of two stable positions, either parallel or antiparallel to the vector of the magnetic field **H**, depending on whether these vectors were at an acute or an obtuse angle to each other in the initial position of the gyroscope.

The motion of the axis of the magnetized conducting gyroscope should consist of the Larmor precession and the rotation, along the shortest path, towards the direction of the field. Actually, if the initial position of the gyroscope shaft is chosen to be at an angle 30—40° to the field, then, after the electromagnet is turned on, the end of the shaft begins to move along a spiral that converges to the field direction, until the axis becomes parallel to the field. If the field direction is reversed during this motion of the gyroscope axis, then only the direction of the convergence of the spiral changes, and the gyroscope axis will continue to approach the field direction without turning over. This is how the orientation of a conducting gyroscope, magnetized along the axis, takes place in an external magnetic field. Each of the vectors characterizing the gyroscope, N and $\mathbf{P}_{m_0}$, can assume one of two stable positions—parallel or antiparallel to the magnetic-field vector **H**. In this respect, the behavior of a conducting magnetized gyroscope is similar to the behavior of an electron in a magnetic field.

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[4] K. N. Baranskiĭ, Usp. Fiz. Nauk 94, 737 (1968) [Sov. Phys.-Usp. 11, 271 (1968)].