ROTATION OF A PLASMA

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Submitted to JETP editor November 4, 1957

J. Exptl. Theoret. Phys. (U.S.S.R.) **34**, 512-513 (February, 1958)

IN a gaseous discharge which takes place in a magnetic field the magnetic lines of forces are "frozen" in the plasma.[1-3] This phenomenon offers the possibility of producing rotational motion of a plasma through the use of a rotating magnetic field.

In the magneto-hydrodynamic approximation, the distribution of particles in an isothermal ideal gas follows the usual centrifugal law. As in the case of mechanical rotation, a rotating conducting gas may be used as an electromagnetic centrifuge. In this connection it is interesting to note that the velocity of rotation is not limited by mechanical considerations.

In the present experiment the plasma was produced in a glass chamber 380 mm high and 60 mm in diameter. The anode, of tantalum, was in the upper part of the chamber. The cathode was liquid mercury. The chamber contained a rotor consisting of four mica vanes fastened to a quartz shaft which was mounted along the axis of the chamber in jewel bearings. The partial pressure of the mercury vapor in the chamber ranged from 10^{-1} to 10^{-3} mm Hg. The rotating magnetic field was set up by two pairs of mutually perpendicular iron-core coils. The current in one pair of coils was shifted in phase by 90° with respect to the current in the other pair. The average field in the neighborhood of the rotor was approximately 325 gauss. At the outset it was established that (1) with the magnetic field on but with no discharge the rotor remained motionless, and (2) when the discharge was excited without the magnetic field the rotor also remained motionless. When the rotating magnetic field was switched on while there was a discharge in the chamber rotation of the rotor was observed. When the magnetic field was reversed, strong deceleration of the rotor was observed; this was followed by acceleration to the maximum velocity.

The discharge current was maintained at 12 amps throughout these experiments. Using a stroboscope it was established that the steady-state speed of the rotor was of the order of 50 rps when the speed of the magnetic field was 50 rps.

Using these results it is possible to estimate the magnitude of the forces which act on the rotor by virtue of the ionized gas which revolves in the rotating magnetic field. The equation of motion of the rotor is $I\,d\omega/dt = M_d - M_f$, where I is the moment of inertia of the rotor with respect to the axis of rotation, $d\omega/dt$ is the angular acceleration, M_d is the moment of the driving force with respect to the axis, and M_f is the moment of the friction forces. It turns out that the friction forces can be neglected in the present case. The moment of inertia of the rotor was calculated and found to be 0.7 g-cm^2. To estimate the moment of the driving forces we assume that $d\omega/dt$ is constant and equal to the mean experimental value. The rotor is accelerated to the steady-state velocity in 0.7 sec at a pressure of 10^{-1} mm Hg; an angular velocity of 50 rps is achieved. Consequently the mean acceleration is of the order of 7 rev/sec^2 or 45 rad/sec^2. Thus $M_d = 31.5$ dyne-cm. Knowing the moment of the forces which act on the rotor we can determine the mean dynamic pressure:

$$P = M_d / 4sr_{av} \approx 1.57 \text{ dynes/cm}^2$$

Since $P = Nmv^2$, $N = P/m\omega^2 r_{av} \approx 2.5 \times 10^{17}$.

The density of charged particles under the present experimental conditions is $10^{11} - 10^{12}$; an estimate of the forces indicates that the rotor is acted on by a gas with a density of 10^{17}, which is approximately equal to the density of the mercury vapor.

In Refs. 4 and 5 a rotating plasma was obtained by exciting a discharge between two coaxial cylinders (electrodes) in a fixed magnetic field. In these experiments plasma rotation arises as a result of the drift velocity $v_\varphi = cE/H$ and the particle distribution is given by $n = AR^\alpha$ where R is the distance from the axis of rotation to the point of observations and $\alpha = \mu c^2E^2/kTH^2$. It is apparent that this method of producing plasma rotation can also be used to make an electromagnetic centrifuge.

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Translated by H. Lashinsky
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