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THE ELECTRODYNAMIC PROPERTIES OF A MIXTURE OF ELECTRIC AND MAGNETIC CHARGES

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It is shown that an assembly of magnetic monopoles can have a negative magnetic permeability at low frequencies. A mixture of a gaseous plasma and such monopoles will also have a negative value of the dielectric permeability. It is shown that in such a mixture there is a light tension (pull) instead of a light pressure. It is also shown that under the action of radiation such a mixture tends to decrease in volume.

As early as 1931 Dirac stated the hypothesis of the existence of a magnetic charge (Dirac monopole)[1] which is a source of magnetic field. The properties of such a monopole have been examined in a review article[2] and also in[3-7]. These papers, however, considered the properties of a single monopole. At the same time it is obvious that if monopoles were to exist, an assembly of them would be the analog of an electron-ion (or electron-hole) plasma. In particular, such a "monopole gas" would have the magnetic permeability

$$\mu = \mu(\omega) = 1 - \omega_M^2/\omega^2. \tag{1}$$

Here $\omega_M^2 = 4\pi N g^2/m$, N is the concentration of monopoles, m their mass, and g the magnitude of the magnetic charge of a monopole.

If we mix a monopole gas and an ordinary plasma, the quantity μ for the mixture will be given by (1), and for ϵ we have

$$\varepsilon = \varepsilon(\omega) = 1 - \omega_0^2/\omega^2. \tag{2}$$

It is not hard to see that for $\omega < \omega_0$ and $\omega < \omega_M$ the ϵ and μ of such a mixture will be negative and isotropic.

Some properties of substances with simultaneous negative values of ϵ and μ have been examined in[8]. It is shown there that in a light beam propagated in a medium with $\epsilon < 0$ and $\mu < 0$ the wave vector **k** is directed opposite to the Poynting vector S. Therefore a light beam propagated in a medium with $\epsilon < 0$ and $\mu < 0$ and falling on a reflecting object will impart to it a momentum $\mathbf{p} = 2N\hbar\mathbf{k}$, where N is the number of incident photons. In accordance with Fig. 1 the result is that the body will experience a force directed toward the source of the light. Accordingly the light pressure characteristic of media with $\epsilon > 0$ and $\mu > 0$ is replaced by a light attraction in media with $\epsilon < 0$ and $\mu < 0$.

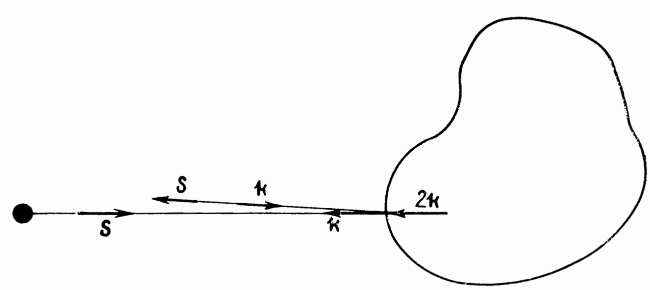

FIG. 1. Reflection of a beam propagated in a medium with $\epsilon < 0$ and $\mu < 0$ from an ideally reflecting body. The black point represents the source of the radiation.

Let us now consider a sphere consisting of a mixture of electric and magnetic charges, situated in vacuum (Fig. 2). We shall assume for simplicity that the sphere has $\epsilon = \mu = -1$. It is not hard to show that in this case a light beam falling radially

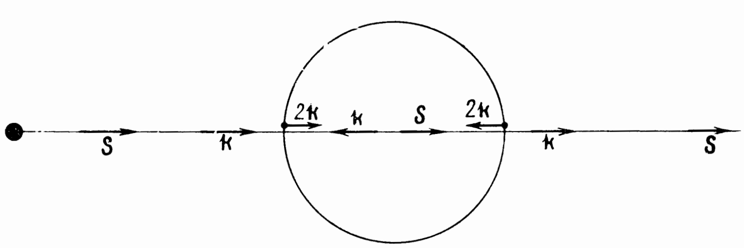

FIG. 2. Passage of a beam through a sphere with $\epsilon < 0$ and $\mu < 0$ situated in vacuum. The black point represents the source of the radiation.

on the sphere passes through it without reflection, and inside the sphere the vector **k** is directed opposite to the vector **S**. Therefore at the points of entry and emergence of the beam the surface of the sphere receives the momentum $\mathbf{p} = 2N\hbar\mathbf{k}$. If the sphere is illuminated from all sides, it will experience a compression from all sides. Therefore a mixture of plasma and Dirac monopoles can evidently not be distributed uniformly in space, since under the action of radiation it will be compressed until such time as the contraction is balanced by some other processes which arise with increase of the concentration of the plasma-monopole mixture. It is possible that this argument to some extent explains the difficulties that have appeared in attempts to observe monopoles experimentally.

In conclusion I express my gratitude to B. M. Bolotovskiĭ, N. V. Karlov, and A. M. Prokhorov for a discussion.

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