

A NOTE ON THE PRESSURE OF RADIATION ON TRANSPARENT DIELECTRICS.

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SYNOPSIS.

Suggested Explanation of Photophoresis, that is the attraction or repulsion of microscopic particles by light as observed by Ehrenhaft and others. It has previously been shown that there are electric and magnetic forces acting on an illuminated transparent body in the direction of propagation of the light if the ether has an electric density (Pe) and a magnetic density (Pm) other than zero. When one dielectric is immersed in another, the difference between these radiation forces per unit volume acting on the two media, would give rise to a relative motion which may be either in the direction of the light or in the opposite direction.

A *Quantum Relation in Maxwell's Electromagnetic Theory* is obtained if we equate the radiation pressure per unit area in terms of Pe and Pm to the pressure derived from the stresses assumed by Maxwell to exist in electric and magnetic tubes of force, namely, the ratio of the amplitude to the wave-length of light is a constant.

THE phenomenon of "negative photophoresis" discovered by Ehrenhaft requires a reëxamination of our notion of radiation pressure. The most serious difficulty in the way of a radiometric interpretation of the phenomenon as given by Westphal and Gerlach, Rubinowicz, Laski and Zerner, etc., is the doubt it throws on the experiments of Lebedew, and Nichols and Hull as having established this radiation pressure. Millikan points out how the droplet suspended in his condenser by the proper electrical field forms an electrical balance that "will weigh accurately and easily to one ten-billionth part of a milligram." Ehrenhaft's condenser using (1) much smaller particles and (2) a microscope in place of a telescope for observations, is quite a thousand times more sensitive. Again, as Ehrenhaft points out (*Ann. d. Phys.*, 56, p. 83) for spherical particles radiation pressure is proportional to the square of the radius while its mass is proportional to its cube so that the acceleration effect would be inversely proportional to the radius and becomes infinitely great for infinitely small values of r . If then under such highly favorable conditions, theoretical as well as experimental, we find the "photophoretic force" almost as often as not ¹ negative in character and if to

¹ An interesting relation between the photophoretic character of an element and its position in the periodic table is given by Mattauch in the following words, "Wie F. Ehrenhaft in einem Vortrage über die Photophorese in der chem.-phys. Ges. in Wien (März, 1919) erwähnte, erweisen sich, soweit die Materialien bisher von ihm und seinen Schülern untersucht sind, Na, K, Cu, Ag, Au, ferner Mg, Zn, Cd und Hg, also die Elemente der Kolonnen I und II des periodischen Systems als lichtpositiv. Lichtnegativ dagegen sind S, P, Sn, Pb und Te, also die Elemente der Kolonnen III und IV und ebenso der Kolonnen V bis VII. Die den letz-

explain the negative sign we are thrown back upon a radiometric explanation, all experiments hitherto done to experimentally establish radiation pressure are naturally discredited.

In this connection attention is invited to a paper by Michaud, who, in order to explain negative photophoresis, showed from thermodynamic considerations the possibility of light pull instead of light pressure for *transparent* substances.¹

In the radiometric interpretation of negative photophoresis it is assumed that it is impossible to explain it on the electromagnetic theory of light.² It would be interesting to examine the *steady* forces in the beam of light mentioned in the note on the plane wave³ for an explanation of negative photophoresis.

The constant intensities in the direction of propagation of a plane wave lead us to a simple expression for the pressure of radiation on transparent bodies. The constant intensities $2\rho_e\Lambda/K$ and $2\rho_m\Lambda/\mu$ give us, by definition, forces acting per unit charge in a direction parallel to that of propagation. The forces per unit volume would be $2\rho_e^2\Lambda/K$ and $2\rho_m^2\Lambda/\mu$ respectively. The mechanical force per unit volume would be the sum of these two forces

$$F = \left(\frac{2\rho_e^2\Lambda}{K} + \frac{2\rho_m^2\Lambda}{\mu} \right).$$

The pressure in the usual form of force per unit area may be derived from the expression

$$F = \frac{1}{2}R \cdot N,$$

where

$$R = \frac{4\pi}{K} \cdot N.$$

Substituting for R the value $2\rho_e\Lambda/K$ we have, therefore, due to the electric force,

$$F_1 = \frac{\rho_e^2\Lambda^2}{2\pi K}.$$

Similarly, due to the magnetic force,

$$F_2 = \frac{\rho_m^2\Lambda^2}{2\pi\mu}.$$

teren Kolonnen angehörenden Elemente As, Se, Sb, Te und J, die in verschiedenen allotropen Modifikationen auftreten, haben aber, wie dortselbst auseinandergesetzt wurde, noch die besondere Eigenschaft dass bei ihrer Verdampfung sowohl lichtpositive als auch lichtnegative Probekörper entstehen." Neue Versuche zur Photophorese, Sitzungsber. d. Wien. Akad. d. Wiss., 129 (IIa), 1920.

¹ C. R., Vol. 168, Nr. 15, 14 April, 1919.

² Zerner and Laski in Zeit. f. Physik., March 4, 1920, p. 226.

³ PHYS. REV., Nov., 1921.

And the resultant force,

$$F = \frac{\Lambda^2}{2\pi} \left(\frac{\rho_e^2}{K} + \frac{\rho_m^2}{\mu} \right). \quad (1)$$

We notice the expression on the right-hand side is of the dimensions of a pressure, and that it is, apparently, independent of the amplitude of vibration in the light disturbance. Maxwell's conception of stresses in the electric and magnetic tubes of force gives us another expression for the pressure, namely $KR^2/8\pi$. Obviously the two expressions are not independent of one another. They are either equal or bear a constant ratio to one another. We have

$$\frac{\rho_e^2 \Lambda^2}{2\pi K} = \frac{c \cdot KR^2}{8\pi}$$

or

$$\frac{R^2}{\Lambda^2} = \frac{1}{c} \cdot \frac{4\rho_e^2}{K^2} = \text{constant}.$$

In words; the ratio between the amplitude and wave-length of light is constant. This interesting relation leads us to a quantum relation in Maxwell's electromagnetic theory and makes the law of equipartition of energy satisfied in the light-wave through ether.

Equation (1) gives us a steady pressure instead of the average of a variable effect and is obtained directly from the fundamental equations. The magnitude of this constant force will depend upon the dielectric. In the case of one dielectric being immersed in another the difference in magnitude of force per unit volume will cause a relative motion parallel to the direction of propagation. The sense of motion, however, can as easily be towards the source of light as away from it. A particle immersed in a fluid gives us a gravitational analogue. The earth's pull exerts a downward force on the particle immersed as well as on each element of the fluid. Whether the particle would rise or sink depends upon whether its gravitational density is smaller or greater than that of the fluid. In this analogy "negative photophoresis" corresponds to buoyancy.

In connection with the "electric density" of dielectrics attention may be directed to an aspect of modern atomic theories. They are not neutral.¹ The necessary excess of charge gives us an electric density.

¹ Broughall, Phil. Mag., Vol. 41, p. 872.
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