

Deviations from the Maxwell Equations resulting from the Theory of the Positron

In spite of its well-known inconsistencies, Dirac's theory of the positron enables one to calculate some physical processes in an unambiguous way; for example, pair creation by photons or by charged particles. Another consequence of this theory, which results from it unambiguously, is the coherent scattering of light by electrostatic fields. It is easily shown that in the latter problem no divergencies occur. The calculation of the polarisability of the vacuum or of scattering of light by light, however, leads to divergent series. To avoid this, Dirac and Heisenberg¹ suggested a convention which allows these infinite expressions to be subtracted.

Owing to the arbitrariness of this formalism, its quantitative results are open to doubt. Among these results are the non-linear additional terms to the Maxwell equations derived by Euler and Kockel². They describe the behaviour of an electromagnetic field containing only frequencies $\nu \ll mc^2/h$. They may be expressed by an addition to the Lagrangian L which for small field-strengths has the form:

$$L = \frac{1}{8\pi} (E^2 - B^2) + \frac{e^4 h}{m^4 c^2} \left[\alpha (E^2 - B^2)^2 + \beta (EB)^2 \right] \dots$$

E being the electric, B the magnetic field strength. This follows directly from relativistic invariance, leaving only the values of the constants α and β undetermined. With the convention mentioned above, these are found to be $\alpha = 1/360\pi^2$, $\beta = 7/360\pi^2$.

We have succeeded in deriving the constants α and β without making use of the subtraction convention of Dirac and Heisenberg. As mentioned above, the scattering of light by electrostatic fields can be calculated without having to deal with divergent expressions. We have done this for fields satisfying the condition

$$|\text{grad } E| \ll |E| \frac{mc}{h}$$

The cross-section for light with frequencies $h\nu \ll mc^2$ is of the order of magnitude:

$$g \sim \left(\frac{e^2}{mc^2}\right)^2 \left(\frac{e^2}{hc}\right)^2 \left(\frac{h\nu}{mc^2}\right)^4 \frac{W}{mc^2}$$

where W is the total energy of the scattering field. The exact expression depends on the angles between the light vectors and the scattering electric field. As this scattering process can be considered as a consequence of non-linear field equations, it can also be calculated by means of the Lagrangian (1).

By comparing the former result with the expression derived from the Lagrangian, the constants α and β are completely determined and one gets the same values as derived with Heisenberg's convention. Thus all the results following from the non-linearity of Maxwell equations, for example, the cross-section for scattering of light by light as found by Euler and Kockel, seem to be of the same trustworthiness as the cross-section for pair production derived by Bethe and Heitler.

The extension of this calculation to the scattering by the nuclear Coulomb field is in progress.

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¹ P. A. M. Dirac, *Proc. Camb. Phil. Soc.*, **30**, 150 (1934). W. Heisenberg, *Z. Phys.*, **90**, 209 (1934).
² H. Euler and B. Kockel, *Naturwiss.*, **23**, 246 (1935).

Pre-Gibbs Adsorption by Surface Rearrangement

It has been an unresolved paradox¹ that for many solutions such as soap the surface tension is only a fraction of that of water, and yet the Gibbs theorem strictly requires that in the neighbourhood of the surface there should be proportionately more water than in the bulk of the solution. When the solution is thoroughly mixed and uniform right up to the surface (dynamic surface tension), the surface tension is practically the same as that of water. After a few thousandths of a second, the surface tension is very greatly lowered, in spite of the accumulation of more water in the surface demanded by Gibbs.

It may therefore be suggested that the surface tension is lowered, not merely by orientation of dissolved molecules which originally chanced to be exposed on the surface, but also that there is an interchange of positions between molecules of solute and solvent within a few molecular diameters of the surface. Thus a solution might almost immediately be partially covered by a layer of solute exposing only hydrocarbon groups and overlying another layer that would be mainly water. Complete coverage could lower the surface tension by more than 30 dynes, as shown by the Pockels-Langmuir-Adam trough with oleic acid on pure water. This would also account for the observation that oleic acid will not spread on the surface of a soap solution, although it does so immediately upon water and upon solutions of most substances.

The conception of pre-Gibbs adsorption by surface rearrangement arises primarily from a series of studies by my collaborators, Drs. T. F. Ford, D. A. Wilson and Mr. G. F. Mills, using solutions of substances such as phenol, caprylic acid, and especially hydrocinnamic acid.

The surface tension of a solution of the latter containing 1.5 gm. per litre is almost instantaneously lowered by at least 10 dynes, but the microtome method shows that the Gibbs adsorption is negligible, the average composition of the surface sandwich layers being still that of the whole solution. The Gibbs adsorption requires many (12) hours to rise to its approximately complete value. Again, an insoluble substance spreads on these freshly swept solutions almost as freely as on water; whereas, after Gibbs' adsorption occurs, spreading is slow and difficult. Further evidence is obtained from the surface tension of freshly swept surfaces and of samples from the same container poured from underneath the surface, from a surface that has been allowed to stand, and from a frothed surface. Our conception, together with the observation that the Gibbs layer is relatively slowly soluble, would explain the fact that a moving bubble may yield reproducible values for adsorption which range from many times smaller to many times larger than Gibbs.

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¹ J. W. McBain and D. A. Wilson, *J. Amer. Chem. Soc.*, **58**, 379 (1936).

Adsorption of Nitrogen on Tungsten

In a recent paper¹, it has been shown that it is possible to study the adsorption of hydrogen and oxygen on a tungsten wire and to measure the heat evolved and the amount of gas adsorbed. Experiments have now been carried out with similar apparatus using nitrogen, and they have shown that, if less