Why Material Quantities Must be Integration Constants

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Let us take force and energy in electromagnetic fields. This is derived for example from several charges, e.g.

$$K = -\frac{Q_1 Q_2}{4\pi\varepsilon|\mathbf{r}_2 - \mathbf{r}_1|^2} \quad , \qquad W = \frac{Q_1 Q_2}{4\pi\varepsilon|\mathbf{r}_2 - \mathbf{r}_1|} \quad . \tag{1}$$

In which, one charge does not act to itself.

The transition to very many and very small charges and currents leads, with tensor notation, to

$$K^\mu = F^\mu{}_\nu S^\nu \quad , \qquad T_{\mu\nu} = F_{\mu\alpha}F_\nu{}^\alpha - \frac{1}{4}g_{\mu\nu}F_{\alpha\beta}F^{\alpha\beta} \quad , \tag{2}$$

with

$$K^\mu = T^{\mu\nu}{}_{;\nu} \quad ,$$

that means, the force density is the divergence of the energy-momentum tensor.

This transition is fairly difficult, because it does not more distinguish what acts to itself and what not. But one can see that the sources, i.e.

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distributed charges and currents, do not appear in the energy and momentum components. Moreover, this energy-momentum tensor meets the EINSTEIN equation only, if the sources vanish. That identically means, the energy law is met only under this condition.

Each try introducing additional terms for the energy-momentum tensor, in order to save the sources, has failed up to now. But there is an alternative: *The integration constants of the source-free* MAXWELL *equations.* Only with them, the unification of gravitation with electromagnetism becomes consistent.

Actually, the discrete charges in equ.(1) are integration constants anyway. Otherwise, above mentioned transition were impossible.

Taking the energy of the field according to equ.(2), one does usually not know how to integrate it.[1] One could doubt if these components are real energies and momenta. For that reason, energy must be an integration constant. With the equivalence of mass and energy, mass is an integration constant too.

Taking the energy-momentum tensor of the distributed mass and the resulting force density

$$T^{\mu\nu} = \rho \, \frac{\mathsf{d}x^\mu}{\mathsf{d}s} \, \frac{\mathsf{d}x^\nu}{\mathsf{d}s} \quad , \qquad K^\mu = \rho \; k^\mu \quad , \tag{3}$$

the clean solution consists in $\rho = 0$. The alternative $k^\mu = 0$ may have heuristic meaning, because it provides equations of motion.[2] But the needed motion is not given in each case.

Under these aspects, only the geometric theory of fields provides the way out of the inconsistencies from any sources.

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[1] An exception is to find in [3].

[2] Geometrically, it describes geodesics.

References :

[1] Wunsch, G.: Theoretische Elektrotechnik. Lectures at Technische Universität Dresden, 1966-1968.

[2] Bruchholz, U.: http://bruchholz.psf.net/article2.pdf , with further references.

[3] Bruchholz, U.: http://bruchholz.psf.net/h-article.pdf .

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