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What is Mass?
4th July 2012
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BROKEN SYMMETRIES AND THE MASSES OF GAUGE BOSONS

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In a recent note\(^1\) it was shown that the Goldstone theorem,\(^2\) that Lorentz-covariant field theories in which spontaneous breakdown of symmetry under an internal Lie group occurs contain zero-mass particles, fails if and only if the conserved currents associated with the internal group are coupled to gauge fields. The purpose of the present note is to report that, as a consequence of this coupling, the spin-one quanta of some of the gauge fields acquire mass; the longitudinal degrees of freedom of these particles (which would be absent if their mass were zero) go over into the Goldstone bosons when the coupling tends to zero. This phenomenon is just the relativistic analog of the plasmon phenomenon to which Anderson\(^3\) has drawn attention: that the scalar zero-mass excitations of a superconducting neutral Fermi gas become longitudinal plasmon modes of finite mass when the gas is charged.

The simplest theory which exhibits this behavior is a gauge-invariant version of a model used by Goldstone\(^2\) himself: Two real\(^4\) scalar about the “vacuum” solution \(\varphi_1(x) = 0, \varphi_2(x) = \varphi_0\):

\[\partial^\mu \{ \partial_\mu (\Delta \varphi) - e \varphi_0 A_\mu \} = 0, \quad (2a)\]

\[\{ \partial^2 - 4 \varphi_0^2 V''(\varphi_0^2) \}(\Delta \varphi_2) = 0, \quad (2b)\]

\[\partial_\nu F^{\mu\nu} = e \varphi_0 \{ \partial_\mu (\Delta \varphi_1) - e \varphi_0 A_\mu \}. \quad (2c)\]

Equation (2b) describes waves whose quanta have (bare) mass \(2\varphi_0 V''(\varphi_0^2)^{1/2}\); Eqs. (2a) and (2c) may be transformed, by the introduction of new variables

\[B_\mu = A_\mu - (e \varphi_0)^{-1} \partial_\mu (\Delta \varphi_1),\]

\[G_{\mu\nu} = \partial_\mu B_\nu - \partial_\nu B_\mu = F_{\mu\nu}, \quad (3)\]

into the form

\[\partial_\mu B^\mu = 0, \quad \partial_\nu G^{\mu\nu} + e^2 \varphi_0^2 B_\mu = 0. \quad (4)\]

Equation (4) describes vector waves whose quanta

BROKEN SYMMETRY AND THE MASS OF GAUGE VECTOR MESONS*

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It is of interest to inquire whether gauge vector mesons acquire mass through interaction with some other charged fields. The most natural candidate for such a field is the Goldstone field which is in its present state of being a scalar.
What is a field?
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SAY GOD PARTICLE

ONE MORE GODDAMN TIME