34(1): ECE Dynamics of a Massive Spin - One Particle

In the standard model these dynamics are not gauge invariant, so violate the gauge principle. In ECE theory the problem can be developed straightforwardly. This is illustrated with the massive photon. In the limit:

$$R T = \left(\frac{mc}{\hbar}\right)^2 \quad -(1)$$

the wave equation of the massive photon is:

$$\left(\Box + \left(\frac{mc}{\hbar}\right)^2\right) A^a_\mu = 0 \quad -(2)$$

which is the Proca equation for each a, i.e. for each polarization:

$$a = (0), (1), (2), (3). \quad -(3)$$

The e/m field is:

$$F^a_{\mu\nu} = \partial_\mu A^a_\nu - \partial_\nu A^a_\mu + \omega^a_{\mu b} A^b_\nu - \omega^a_{\nu b} A^b_\mu . \quad -(4)$$

Thus:

$$\partial^\mu F^a_{\mu\nu} = \Box A^a_\nu + \partial^\mu \left(\omega^a_{\mu b} A^b_\nu - \omega^a_{\nu b} A^b_\mu\right). \quad -(5)$$

Eq. (2) is the equation of the free photon of mass m. Comparing eqs (2) and (5):

$$\left(\frac{mc}{\hbar}\right)^2 A^a_\nu = \partial^\mu \left(\omega^a_{\mu b} A^b_\nu - \omega^a_{\nu b} A^b_\mu\right) \quad -(6)$$

This is a <u>free space</u> equation, because we are considering a free photon, i.e. one free of the gravitational field of matter, such as the electron.

Now use:

$$A^a_\nu A^\nu_a = 4 A^{(0)2} \quad -(7)$$

to find:

$$\boxed{m^2 = \frac{\hbar^2}{4c^2 A^{(0)2}} A^\nu_a \partial^\mu \left(\omega^a_{\mu b} A^b_\nu - \omega^a_{\nu b} A^b_\mu\right)} \quad -(8)$$

Also from eq. (6):

$$\left(\frac{mc}{\hbar}\right)^2 \partial^\nu A^a_\nu = 0 \quad -(9)$$

so

$$\boxed{\partial^\nu A^a_\nu = 0} \quad -(10)$$

From eq. (8) the photon mass is:

$$\boxed{m \sim 10^{-42} \text{ kgms}} \,. \quad -(11)$$

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From eq. (10) we see that the Lorentz condition always holds. From eq. (8) the photon mass is due to the spin connection.

In the presence of matter:

$$\left(\frac{mc}{\hbar}\right)^2 \rightarrow kT \qquad -(12)$$

and

$$\partial^\mu F^a_{\mu\nu} \neq 0 \qquad -(13)$$

This introduces the inhomogeneous current, so that

$$\partial^\mu F^a_{\mu\nu} = \mu_0 J^a_\nu \qquad -(14)$$

So J^a_ν is traced to the difference between kT and $(mc/\hbar)^2$.

Standard Model

The Proca equation is:

$$F^{\mu\nu} = \partial^\mu A^\nu - \partial^\nu A^\mu \qquad -(15)$$

$$\partial_\mu F^{\mu\nu} + \left(\frac{mc}{\hbar}\right)^2 A^\nu = 0 \qquad -(16)$$

so:

$$\left(\frac{mc}{\hbar}\right)^2 \partial_\nu A^\nu = 0 \qquad -(17)$$

and

$$\left(\Box + \left(\frac{mc}{\hbar} \right)^2 \right) A_\nu = 0 \quad - (18)$$

The lagrangian for the Proca equation is:

$$\mathcal{L} = -\frac{1}{4} F_{\mu\nu} F^{\mu\nu} + \frac{1}{2} m^2 A_\mu A^\mu \quad - (19)$$

(reduced units).

This poses a fatal weakness for the standard model because neither eq. (19) nor eq. (17) is gauge invariant. A massive spin one particle cannot be understood with the gauge principle.

In ECE this is not a problem because the gauge principle is not used. In ECE the origin of photon mass is traced to the spin connection.