Using Potentials for E&M and QM/QFT

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We are used to E and B force fields, but QFT uses the potentials ϕ and A instead. **Can we "understand" E&M conceptually better by just using potentials?**

(see http://sackett.net/ElectromagnetismFromPotentials.pdf – might be a little difficult but shows that potentials suffice).

Carroll's book doesn't mention the EM vector potential A until page 200 {he calls it the "photon field"}. *He does refer to force fields E and B, but he doesn't use them.* On page 202 he introduces *a "covariant derivative"* $\hat{D} = (\partial_\mu - iA_\mu)$ on an electron's wavefunction. By this, he means starting with the usual "kinetic momentum" as an operator: p= mv = P_c – qA = where "*canonical momentum*" is P_c = mv + qA (adding mechanical and electromagnetic momentum **together**). Then, like usual QM, $\hat{P}_c$ à $-i\hbar\nabla$ so that $\hat{p}\psi = (-i\hbar\nabla - qA)\psi = -i\hbar\,(\nabla - iqA/\hbar)\psi$. {notice that he dropped $\hbar \equiv 1$ and charge q=e}.

Best Wishes, Dave

Cosmo Side Readings

David Peterson 10/29/2024 2:21 PM

COSMO: *some additional information on current studies*

EDE, Early Dark Energy: For enhanced early galaxy formations possibly going beyond the recent Scientific American article on "Cosmic Confusion," see:
https://news.mit.edu/2024/study-early-dark-energy-could-resolve-cosmologys-two-biggest-puzzles-0913
https://academic.oup.com/mnras/article/533/4/3923/7750120?login=false "Early galaxies and early dark energy: a unified solution to the Hubble tension and puzzles of massive bright galaxies revealed by *JWST, "Oct 2024*

Note that the Standard ΛCDM model of Cosmology is not yet completely worked out and has a list of outstanding problems -- see the section topics after "Challenges" in the Wikipedia summary:
https://en.wikipedia.org/wiki/Lambda-CDM_model

GW Detections: LIGO, Virgo, and KAGRA began their 4th joint observing run on 24 May 2023. O4 will continue until February 2025. (latest was 10/11/24). All O4 are BH/BH with masses > 5 $M_{\odot}$. (we are hoping to see more NS/NS mergers). https://en.wikipedia.org/wiki/List_of_gravitational_wave_observations

The Wikipedia articles on Neutron Stars and Pulsars are nice. https://en.wikipedia.org/wiki/Neutron_star https://en.wikipedia.org/wiki/Pulsar

It seems that Sean Carroll's Quanta and Fields will be our next study. As usual, a goal is to advance our individual levels of understanding another step higher.

We say that an elementary particle is an excitation of its particular type of quantum-field which exists and is duplicated throughout all of the space-time "Vacuum." So, a central key to QFT is that "the Vacuum is Not Nothing!" --It is a Thing. It may be considered as the most important thing in physics. A concrete example of this is shown in the Figure "Particle Creation out of the Vacuum" on Page 12 of http://www.sackett.net/AboutQuantumFieldTheory.pdf -- perhaps the most revealing plot in the history of physics (my opinion). It implies that the "knowledge" and "Forms" of fundamental particles and fields pre-exist everywhere all around us all the time. An equivalent "dimuon" plot is shown at:
https://www.science20.com/quantum_diaries_survivor/blog/atlas_vs_cms_dimuon_resonances-75594

With a supply of local energy, elementary particle pairs {quark-anti-quark mesons} ***can just "pop out of the Vacuum"*** *of space-time as seen from Lepton colliders for e-e+ or deduced for μ-μ+ annihilation into photons. As input energy is increased in giga-electron-volts, we first* ***emerge*** *quark-meson combinations of $u\bar{u}$ & $d\bar{d}$ quarks called ρ or ω mesons. This is followed by $s\bar{s}$ or ϕ mesons, then charmonium $c\bar{c}$ or ψ mesons and $b\bar{b}$ = Y (upsilon) mesons {t, or top-quarks, don't live long enough to actualize}. Finally we see Z^0 particles (the neutral weak boson or "heavy photon"). The thin vertical spikes show that the incoming energy has to be precisely on target to stimulate the heavy meson resonances of the various quantum fields. {The ρ' is an excited state of ρ, and the ψ(2S) is an excited state of the J/ψ (1S)}.*

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