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New method of fast calculating lepton magnetic moments in quantum electrodynamics

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A high-precision calculation of lepton magnetic moments requires an evaluation of QED Feynman diagrams up to five independent loops.

These calculations are still important:

1) the 5-loop contributions with lepton loops to the electron g-2 are still not double-checked (and can potentially be sensitive in experiments);

2) there is a discrepancy in different calculations of the 5-loop contribution without lepton loops to the electron g-2;

3) the QED uncertainty in the muon g-2 is estimated as negligibly small relative to the hadronic one, but there are a lot of questions for those estimations.

Using known universal approaches (based on dimensional regularization and so on) for these purposes leads to an enormous amount of computer time required. To make these calculations feasible it is very important to remove all divergences before integration and avoid limit-like regularizations at intermediate stages. The direct usage of BPHZ is not possible due to infrared divergences of complicated structure.

I had already developed a method of divergence elimination some years ago. That method allowed us to double-check the 5-loop QED contribution without lepton loops to the electron g-2.

A new method of doing this will be presented. Both methods are based on applying linear operators to Feynman amplitudes of ultraviolet divergent subdiagrams. This is similar to BPHZ; the difference is in the operators used and in the way of combining them. Both methods are suitable for calculating the universal (mass-independent) QED contributions to the lepton anomalous magnetic moments: they are equivalent to the on-shell renormalization; the final result is obtained by summation of the diagram contributions; no residual renormalization is required.

However, the new method has some advantages relative to the old one:

1) it works for calculating the contributions dependent on the relations of particle masses (for example, muon and electron);

2) it preserves gauge-invariant classes of diagrams with lepton loops (including mass-dependent ones).

The new method is a next step towards the dream of the general case regularization-free perturbative calculation in quantum field theory.

Significance

1. It gives a way to calculate the QED contribution to the muon anomalous magnetic moment honestly, without presumptuous unjustified statements that it is well known.

2. It gives an ability to obtain all QED contributions to the electron anomalous magnetic moment in minimal gauge-invariant classes. The effectiveness of the method allows us to calculate the 5-loop contributions. It is very important for independent checking and theoretical investigations.

3. The method is a further development of an effective approach to perturbative calculations in quantum field theory. In the future, this approach can be applied to other important problems.

References

Numerical calculation of 5-loop QED contributions to the electron anomalous magnetic moment (ACAT-2019):
https://iopscience.iop.org/article/10.1088/1742-6596/1525/1/012007

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Numerical calculation of high-order QED contributions to the electron anomalous magnetic moment:
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New method of computing the contributions of graphs without lepton loops to the electron anomalous magnetic moment in QED:
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