Running couplings and operator mixing in the gravitational corrections to coupling constants

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The use of a running coupling constant in renormalizable theories is well known, but the implementation of this idea for effective field theories with a dimensional coupling constant is in general less useful. Nevertheless there are multiple attempts to define running couplings including the effects of gravity, with varying conclusions. We sort through many of the issues involved, most particularly the idea of operator mixing and also the kinematics of crossing, using calculations in Yukawa and lambda phi^4 theory as illustrative examples. We remain in the perturbative regime. In some theories with a high permutation symmetry, such as lambda phi^4, a reasonable running coupling can be defined. However in most cases, such as Yukawa and gauge theories, a running coupling fails to correctly account for the energy dependence of the interaction strength. As a byproduct we also contrast on-shell and off-shell renormalizaton schemes and show that operators which are normally discarded, such as those that vanish by the equations of motion, are required for off-shell renormalization of effective field theories. Our results suggest that the inclusion of gravity in the running of couplings is not useful or universal in the description of physical processes.

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