

Timelike Entanglement First Law and Linearized Field Equations in Higher Curvature Gravity

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We investigate the timelike entanglement first law in holographic conformal field theories whose bulk dual is Lovelock gravity. Using the double Wick rotation formulation of timelike entanglement entropy together with the Jacobson-Myers entropy functional, we compute the linear variation of holographic timelike entanglement entropy for hyperbolic subregions. For cubic Lovelock gravity, we explicitly show that a single, universal multiplicative renormalization factor governs how higher curvature interactions enter the variations of both the entropy and the modular Hamiltonian, leading to $\Delta S = \Delta \langle H \rangle$ for low-energy thermal excitations. We then extend the analysis to Lovelock gravity of arbitrary order around the anti-de Sitter spacetime in the Fefferman-Graham gauge. For normalizable perturbations, the variation of the Jacobson-Myers functional reduces to the Einstein gravity's result multiplied by the same coupling-dependent factor that renormalizes the effective Newtonian constant in the linearized field equations of Lovelock gravity. We further show that the boundary contribution vanishes in the conformal limit for the class of perturbations considered. Consequently, the timelike entanglement first law is equivalent to the linearized field equations of Lovelock gravity about the maximally symmetric background.

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