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How do classical particle-field systems become unstable? – The last physics problem that Ronald Davidson studied.[1]

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Many of the classical particle-field systems in (neutral and nonneutral) plasma physics and accelerator physics become unstable when the system parameters vary. How do these instabilities happen? It turns out, very interestingly, that all conservative systems become unstable by the same mechanism, i.e, the resonance between a positive- and a negative-action modes. And this is the only route that a stable system can become unstable. In this talk, I will use several examples in plasma physics and accelerator physics with finite and infinite degrees of freedom to illustrate the basic physical picture and the rigorous theoretical structure of the process. The features at the transition between stable and unstable regions in the parameter space are the fundamental characteristics of the underlying real Hamiltonian system and complex G-Hamiltonian system. The resonance between a positive- and a negative-action modes at the transition is the Krein collision well-known to mathematicians.

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