Though the perturbation theory has been successfully used to describe various types of responses of molecules to electromagnetic fields for a long time, the extension of this theory to solids is not straightforward since the position operator is ill defined for such systems. The theoretical description of magnetic fields in periodic systems is particularly challenging as it leads to non-perturbative changes in eigenstates. We present a unified approach to calculation of all-order response to arbitrary electromagnetic fields both for periodic and molecular systems within the formalism of non-equilibrium Green functions. The approach is used to analyze magneto-optical response of insulating solids in the approximation of non-interacting electrons and to identify symmetry limitations for its observation. The density matrix-perturbation theory is adapted for practical calculations of magneto-optical response and is implemented in open-source Octopus code using efficient Sternheimer method for solution of the Liouville equation. The implemented procedures are tested against available literature data for molecular and crystalline systems.