

Computational Quantum Physics

Week 8

Due on Week 9

Exercise 1: **Density Matrices**

Consider a quantum system formed by N subsystems (spins, atoms, particles etc..) each described by its wave function $\psi_i \in \mathcal{H}^D$ where \mathcal{H}^D is a D -dimensional Hilbert space.

- (a) How do you write the total wave function of the system $\Psi(\psi_1, \dots \psi_N)$? Write a Fortran code to
 - 1) describe such a system (N -body non interacting, separable pure state) and
 - 2) a general N -body pure wave function $\Psi \in \mathcal{H}^{D^N}$.Comment on their efficiency.
- (b) Given $N=2$, write the density matrix of a pure state Ψ , $\rho = |\Psi\rangle\langle\Psi|$.
- (c) Given a generic density matrix in \mathcal{H}^{D^2} compute the reduce density matrix of either the left or the right system, e.g. $\rho_1 = \text{Tr}_2 \rho$.
- (d) Test the functions described before (and all others needed) on two-spin one-half (qubits) with different states.