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Finite quantal systems – from semiconductor quantum dots to cold atoms in traps[1]

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Many-body systems that are set rotating may form vortices, characterized by rotating motion around a central cavity. This is familiar to us from every-day life: you can observe vortices while stirring your coffee, or watching a hurricane. In quantum physics, vortices are known to occur in superconducting films and rotating bosonic He-4 or fermionic He-3 liquids, and recently became a hot topic in the research on cold atoms in traps. Here we show that the rotation of trapped particles with a repulsive interaction may lead to vortex formation regardless of whether the particles are bosons or fermions. The exact many-particle wave function provides evidence that the mechanism is very similar in both cases. We discuss the close relation between rotating BECs and quantum dots at strong magnetic fields. The vortices can stick to particles to form composite particles, but also occur without association to any particular particle. In quantum dots we find off-electron vortices that are localized, giving rise to charge deficiency or holes in the density, with rotating currents around them. The vortex formation is observable in the energetics of the system. "Giant vortices" may form in anharmonic potentials. Here, the vortices accumulate at the trap center, leading to large cores in the electron and current densities. Turning from single traps to periodic lattices, we comment upon the analogies between optical lattices with cold fermionic atoms, and regular arrays of few-electron quantum dots. Trapping a few ($N < 12$) fermions in each of the single minima of the lattice, we find that the shell structure in the quantum wells determines the magnetism, leading to a systematic sequence of non-magnetic, ferromagnetic and antiferromagnetic states.

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