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Thermomagnetic convection as a novel heat transfer mode in electronics cooling

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Ferro fluids behave as electrically non-conducting, isotropic, homogeneous continua and combine the dual attributes of magnetic response and liquid flow ability. When subjected to external magnetic fields, the particle magnetic moment vectors align with the (applied) field direction without hysteresis. For all values of the magnetic field strength, the magnetization behaviour can be described by the Langevin function, which is characterized by a high initial susceptibility at low to moderate fields followed by a low susceptibility due to magnetic saturation. This super paramagnetic behaviour can be harnessed to establish flow in devices through external positioning and control of magnetic fields without the aid of movable parts. Externally imposed and controllable magnetic field gradients, coupled with thermally induced ferro-fluid susceptibility gradients (e.g. by boundary heating from localized heat sources), result in thermomagnetic convection. Under externally-applied magnetic field and temperature gradients, thermomagnetic transport can initiate advective motion without external pumping action. It causes heat removal from the sites of "hot-spots" of devices through active "participation" by the heat sources themselves. Thermomagnetic convection can, therefore, be used as a viable heat transfer method in microgravity environments, or serve as a novel mechanism to augment free convection in electronics cooling. This convection mechanism also aids in designing self-regulating and self-sustaining thermo syphon-type passive cooling systems for electronics cooling, where the pertinent small length scales render buoyancy-aided convection rather ineffective.

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Computational fluid dynamics based on the unified coordinates

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Computational fluid dynamics (CFD) uses large scale numerical computation to solve problems of fluid flow. Traditionally, it uses either the Eulerian or the Lagrangian coordinate system. These two systems are numerically non-equivalent, but each has its advantages as well as drawbacks. A unified coordinate system (UC) has recently been developed which combines the advantages of both Eulerian and Lagrangian systems, while avoiding their drawbacks. This talk gives a systematic discussion on CFD using the unified coordinates. It will be shown that: (1) The governing equations of fluid flow in any moving coordinates can be written as a system of closed conservation PDEs, thus enabling correct capturing of shocks; (2) the system of Lagrangian gas dynamics equations is written in conservation PDE form for the first time, providing the foundation for developing Lagrangian schemes as moving mesh schemes in Eulerian space; (3) the Lagrangian gas dynamics equations in 2-D and 3-D are shown to be non-equivalent to the Eulerian ones, theoretically. Computationally, (4) the UC is shown to be superior to both Eulerian and Lagrangian systems in that, contact discontinuities are resolved sharply without mesh tangling; (5) the UC avoids the tedious and time-consuming task of mesh generation in the Eulerian method for flow past a body; the mesh in UC is automatically generated by the flow; (6) the UC represents a new moving-mesh method, where the effects of moving mesh on the flow are fully accounted for. Many examples are given to demonstrate these properties of the UC.

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