Isaac Newton Institute for Mathematical Sciences

Granular and Particle-Laden Flows

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This research programme at the Newton Institute will be devoted to improving our understanding of granular and particle-laden fluid systems as they arise in nature, in the laboratory and in industry. Geophysical examples are debris flows, mud flows, and turbulent boundary layers with suspended particles, such as volcanic ash flows, underwater turbidity currents, and powder snow avalanches (central figure). Industrial examples are flows of cereals, pharmaceuticals, aluminium, coal, and concrete in storage facilities, production lines, power stations, and construction sites.

Mathematicians and physicists are fascinated with such flows because they involve a wide range of flow regimes, some of which exhibit interesting patterns, chaotic motion, and transitions between structure and chaos. For example, the familiar phenomena of grain segregation by size, mass, or other properties may be transformed into chaotic mixing by varying the speed of the flow. This can be seen in figures 1 and 2 in a mixture of large (dark) grains and small (white) particles that flows in a narrow gap of a short cylindrical drum that rotates about its central axis.

The mathematical description of granular and particle-laden flows presently proceeds on a case-by-case basis using relatively simple ad-hoc to involve a range of complex and sophisticated theoretical concepts and to require an interdisciplinary approach. Therefore, the time appears to be ripe for a concerted effort among mathematicians, physicists, and engineers to study the fundamental mechanisms responsible for the various observed phenomena and to unify the seemingly disparate models.

Three specific topics will be addressed:

i. Particle-laden flows: theoretical modelling with emphasis on geophysical flows ranging from sediment transport to powder snow avalanches.

ii. Pattern formation and chaos: the mathematical description of patterns and their dynamics in controlled experiments on flow segregation and vibrated layers.

iii. Localization, type change, and transition: the physical and mathematical issues associated with failure, jamming, surging, and other rapid changes between flow regimes.

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A homogeneous dry mixture of large (dark) and small (white) particles flows in the narrow gap of a short cylindrical drum that rotates about its axis (Figs. 1 and 2). Depending upon the angular velocity of the rotation, the particles will segregate by size and form a Catherine wheel pattern (1) or they will mix chaotically (2).