5 Dilute systems

This chapter considers the behaviour of a single particle suspended in a fluid. In practice, the equations and principles described are used to understand how a number of particles behave, provided that the concentration is sufficiently low enough to ensure that the behaviour of the particle under consideration is not significantly interfered with by the presence of other particles. Applications of the principles covered include particle size analysis by sedimentation methods; where the settling rate is related to the size of the particle, and the industrial process of *clarification* by sedimentation: in which particles are removed from a fluid stream by allowing sufficient time for the particles to settle.

Archimedes' principle
States that when a body is wholly or partially immersed in a fluid it experiences an upthrust equal to the weight of the fluid displaced

5.1 Weight, drag and Particle Reynolds number

All forces must reduce to Newton's basic equation

$$F = ma$$

Forces either cause particle motion in a fluid, or resist it. A force *balance* can be written using all the forces described, or some of these. The easiest force to appreciate is the particle weight, but this is just one example of a *field force*. The particle weight is the product of its mass and the gravitational acceleration. Particles are usually too small to weigh; hence the particle diameter is used to calculate the volume, which is then multiplied by the density to give the mass. Thus, for a spherical particle, the particle weight is (in Newtons)

$$\frac{\pi x^3}{6}\rho_s g \qquad (5.1)$$

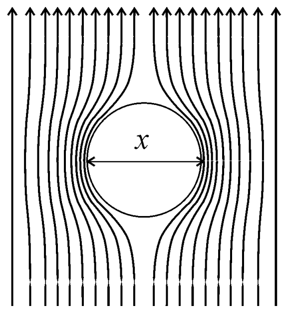

Fig. 5.1 Flow streamlines in fluid around a sphere

However, the particle will experience an upward force, in accordance Archimedes' principle, which numerically is

$$\frac{\pi x^3}{6}\rho g \qquad (5.2)$$

Hence, combining equations (5.1) and (5.2) provides the *buoyed* particle weight

$$\frac{\pi x^3}{6}(\rho_s - \rho)g \qquad (5.3)$$

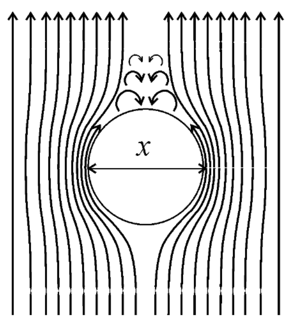

Fig. 5.2 Streamlines and turbulences in a fluid around a sphere – at higher Re'

Before considering other field forces it is illustrative to conduct a simple force balance to see the application of this approach. In a fluid, particle weight will cause an acceleration that will be resisted by fluid drag. When the fluid drag force is equal to the particle weight the motion will be uniform; i.e. no longer accelerating and the particle will attain its *terminal settling velocity*. Fluid drag force comes from a suitable solution to the Navier-Stokes equation. However, this has only been achieved analytically under conditions of no turbulence within the fluid; i.e. streamlines of fluid flowing past the particle, as