moderate $D_e<75$ observed in the microfluidic systems described herein, the secondary rotational flow, or Dean flow, consists of only two vortices. The velocity magnitude of the Dean flow scales as $U_D \sim \rho D_e^2/(\mu D_h)$ and therefore, Stokes drag on suspended particles due to this secondary flow becomes significant for large D_e. In particular, the Dean flow velocity dependence on Dean number can be seen in FIG. **6**B. FIG. **6**B illustrates a simulation of Dean flow at an average streamwise velocity of 1 m/s, corresponding to a Dean number of ~10. The geometry in FIG. **6**B is 50-μm in width at the smaller turn and 80-μm at the larger turn. The main flow is coming out of the page. FIG. **6**C is a graph further illustrating average secondary flow (vortex) velocity magnitude as a function of changing Dean number for a single geometry. A quadratic relationship between D_e and average vortex velocity is observed for a constant geometry and agrees with theory.

[0157] In general, the drag due to Dean flow, or Dean drag (F_D) scales as

$$F_D \sim \frac{\rho U_m^2 a D_h^2}{r}.$$

[0158] Equilibrium separations can be conducted considering the balance of these two forces, Dean drag **64** and inertial lift **66**, as shown in FIG. **7**. In particular, FIG. **7** illustrates the cross-section of any asymmetric curved channel depicting the superposition of the four stable positions **68***a*, **68***b*, **68***c*, **68***d* due to inertial lift forces with the Dean flow. A possible mechanism for biasing a single minimum is also presented. The dominant viscous drag due to the Dean flow acts strongly at the channel mid-line, directing particles to one side of the channel over the other (for the opposite turn this force is of less magnitude in the opposite direction, and does not surpass the inertial force). Once a particle **70** is trapped in this minimum, it can remain because the viscous drag **64** at the split point of the two vortices is less in magnitude than the shear gradient-induced lift **66**. Particles at the top and bottom minimum may not remain trapped because the viscous drag acts strongly here as well, and in the direction of a weaker shear gradient.

[0159] The ratio of lift to drag forces, R_f scales as $R_f \sim \delta^{-1}(a/D_h)^3$ for a constant R_c. Separations are ideal when $R_f \geqq 1$ within the channel cross section for a particle of a given size and less than 1 for a particle of another size. For R_f, lift forces that push particles to an equilibrium position dominate, while for $R_f<1$, dominant Dean drag overwhelms these equilibrium positions and leads to mixing of particles. The dependence on particle diameter cubed suggests effective separation of particles with small size differences. The R_f relation also suggests that the separation can be tuned to separate particles over a range of diameters by modification of the geometry D_h and curvature ratio (δ).

[0160] Theory predicts a limit to the speed of equilibrium separations. Previously, the dependence of the lift/drag ratio, R_f, on R_c was neglected. When this dependence is taken into account, velocities higher than optimum are predicted to lead to defocusing. This is because the inertial lift force scales with the channel velocity squared (U_m^2) and the lift coefficient (f_c), where the lift coefficient decreases with increasing U_m. Therefore, the inertial lift force increases at a rate less than U_m^2. This can be compared to the drag force due to Dean flow which scales with U_m^2. This leads to the ratio of these forces, R_f, decreasing with increasing U_m^2.

[0161] Therefore, three flow regimes can be considered: (1) At low fluid velocities, R_f may be larger than 1 over the majority of the channel cross section; however, the magnitudes of F_z and F_D are too low to create focused streams within the length of channel. (2) At intermediate fluid velocities, R_f may be greater or equal to 1 over a limited region of the channel cross section, and the magnitude of forces is large enough to create focusing to one or more streams. (3) For high fluid velocities, R_f is less than 1 over the entire channel cross section, and Dean drag is dominant, leading to particle mixing.

[0162] Using R_f one can predict the particle size cutoff below which focusing does not occur. R_f varies in magnitude across the channel cross section due to variation in F_D and F_z over this region. The functional form of this variation, however, is not currently known and thus it is difficult to predict a priori a particle size cutoff for a given geometry (i.e., for what particle size does R_f initially become <1 throughout the channel cross section). Thus, empirically determined cutoffs can give unknown parameters in R_f. The known geometry and cutoff can then be inserted into the equation $R_f=1$ to find the scaling of unknown positional dependent factors. This is because the particle diameter below which the ratio, R_f first becomes less than 1 over the entire channel cross section corresponds to the size cutoff in that channel geometry. In other words, with decreasing particle diameter, R_f decreases to less than 1, resulting in particle mixing due to Dean drag forces dominating.

[0163] A semi-empirical relationship is provided quantitatively as follows: First, the condition $R_f(x_{c1})=k(ra_c^3/D_h^4)=1$ is produced, where x_{c1} are the coordinates of the final position to become less than 1 within the channel cross section and k is a scaling factor. The empirical parameters are the channel radius of curvature (r), the cutoff size (a_c), and the channel hydraulic diameter. Solving for k for one or more experimental systems allows the development of a relationship that can be applied to an unknown system and size cutoff:

$$r_2\frac{a_{c2}^3}{D_{h2}^4} = r_1\frac{a_{c1}^3}{D_{h1}^4}$$

[0164] This treatment assumes that both systems are operated at a constant R_c and that particle sizes are small compared to the flow field, since x_{c1} is assumed to remain independent of particle size.

[0165] A simplified expression that dictates the geometry of a new channel to separate at a new cutoff can then be developed. If the same radius of curvature is maintained, then an empirical relation for D_h as a function of the cutoff diameter can be written as:

$$D_{h2} = D_{h1}\left(\frac{a_{c2}}{a_{c1}}\right)^{3/4}$$

[0166] If height is the dominant factor in determining the inertial lift force and channels with large widths are considered, such that h is the dominant dimension for Dean flow, the equation for D_{h1} above can be rewritten as $h_2=h_1(a_{c2}/a_{c1})^{3/4}$. In general, particles close to the center and outer wall will