Biological Hydrodynamics

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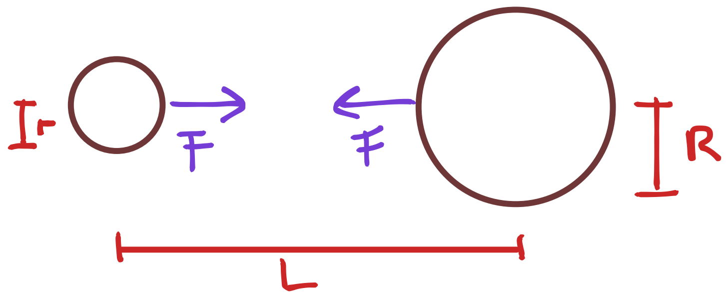
Next Tutorial: Thursday **5th December**, 14:50 - 16:20, MPI PKS Seminar Room 3

Tutorial 6: Hydrodynamic interactions between multiple beads

1. **Two beads**

   Consider two beads, one of radius r and one of radius R that are immersed within an incompressible Newtonian fluid of viscosity η. They are a distance L apart. For a time t, both beads exert an attractive force F upon each other.

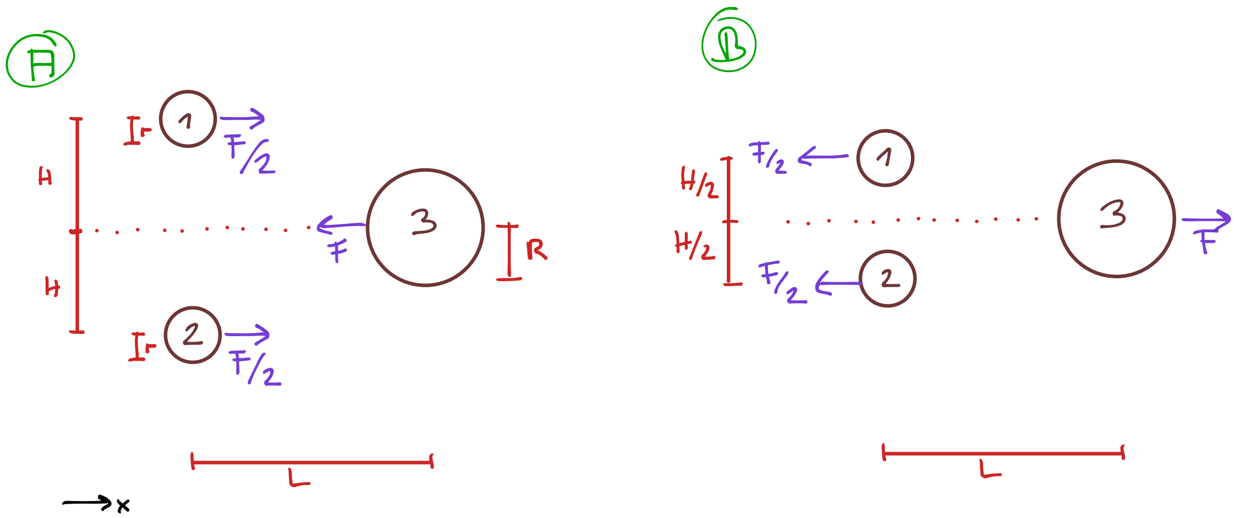


   1.1) How far does each of the beads move? When evaluating the hydrodynamic interaction between the beads, assume that L is much larger than R and r, and that t is small enough so that L does not change considerably for the time that the attractive force is generated. (Hint: Use the Oseen-tensor for point particles to evaluate the hydrodynamic interaction.)

   1.2) In a second step, both beads exert a repulsive force of the same magnitude F upon each other, for the same time t. Will this move the two beads back to their original positions, or will the system have displaced?

2. **Three beads**

Now consider one large bead (No. 3) of radius R and two small beads (No. 1 and 2) of radius r. Beads 1 and 2 are separated from bead 3 along the x direction by a distance L, and beads 1 and 2 are themselves separated by a distance $2H$, see illustration A.



The following force generation protocol is applied: In a first step, an attractive force of magnitude $F/2$ is generated between bead 1 and 3 and between bead 2 and 3 for a time t, see illustration A. These forces act along the x-direction only. In a second step an attractive force is generated between beads 1 and 2, which reduces their separation distance to H. This process is assumed to not affect bead 3. In a third step, a repulsive force of magnitude $F/2$ is generated between bead 1 and 3 and between bead 2 and 3 again for a time t, see illustration B. Again, these forces only have components in the x-direction. In a fourth step, a repulsive force is generated between beads 1 and 2 to increase their separation distance back to $2H$, without affecting bead 3.

2.1) How far are the beads displaced along the x direction after step 1 and 3? For evaluating hydrodynamic interactions, again assume that L is essentially constant throughout the entire cycle.

2.2) By repeating the cycle, will the system swim forward? However, would you expect beads 1 and 2 to maintain a constant distance to bead 3 when the cycle is repeated?