SMS-204: Integrative marine sciences.

Homework 5, Reynolds #, flows and swimming.

1. (60/100) Using data from Lab 1, determine the drag force on a sinking sphere, assuming that when the spheres reach constant settling speed and no net force is acting on the bead:

$$F_{drag}=F_{gravity}-F_{buoyancy}=gV_{sphere}(\rho_{sphere}-\rho_{glycerin})$$

Where g is the gravitational acceleration, V_{sphere} the sphere volume (from lab 1) and ρ the density of the metal spheres, ρ_{sphere}=7800Kg/m^3, and glycerin $\rho_{glycerin}$=1200Kg/m^3.

a. Compute the Reynolds number (*Re*) for all different settling spheres (assume that for glycerin μ=1Kg/s/m (Pa s) and ρ~1.25g/ml (be careful to be consistent with units…).

median bead diameter [cm]	Median settling speeds [cm/s]	Re [unitless]	F_d [N]
0.32	3.5	**0.14**	0.001
0.50	7.5	**0.47**	0.004
0.64	12.7	**1.01**	0.009
1.05	25.3	**3.34**	0.040
1.30	38.0	**6.18**	0.074

b. Plot F_{drag} (based on the equation above) as function of velocity x diameter (W x D = velocity times the diameter). The data from lab 1 is on the class's web site. Is the relationship linear (don't forget to add error bars based on the different estimates for velocity obtained by the different groups)? Obtain the regression line for the plot, that is an expression of the type: F_{drag}= slope x W x D + constant, and provide the equation of the fit on the graph.

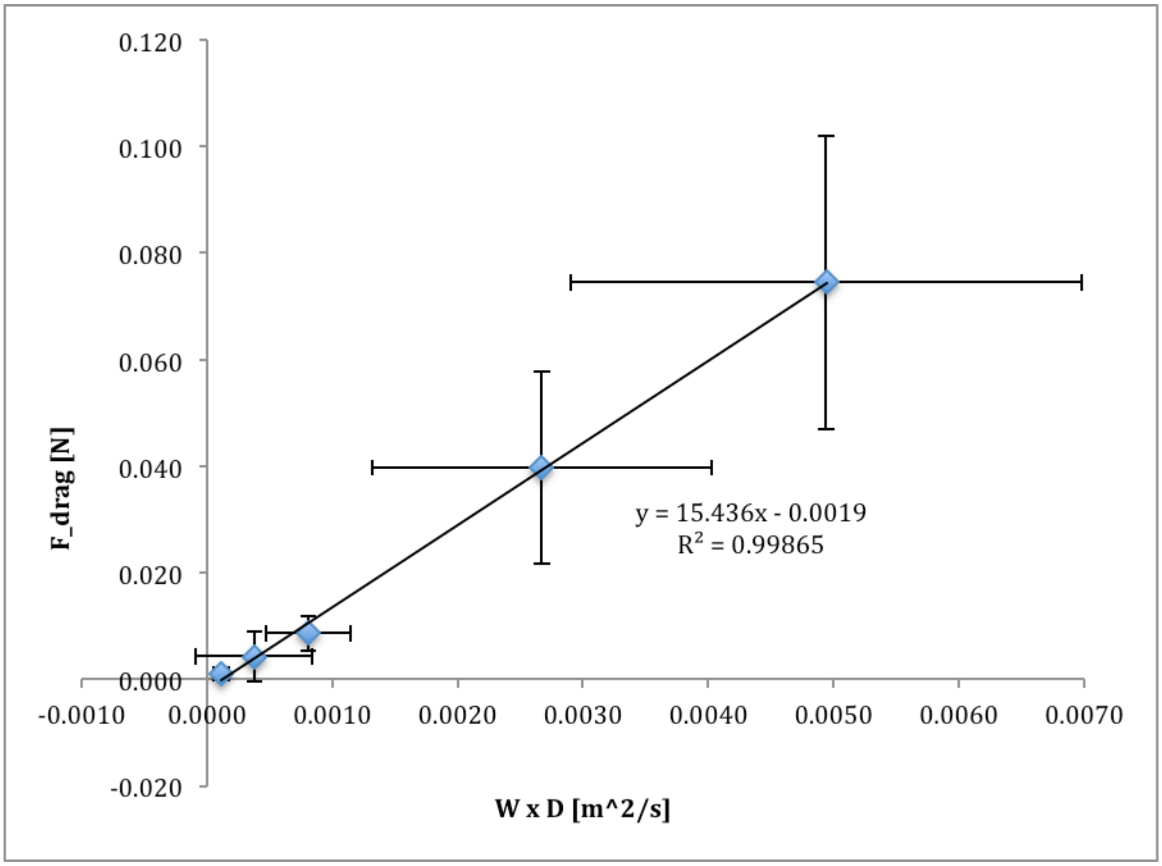

Figure 1. Drag force (=$gV_{sphere}(\rho_{sphere}-\rho_{glycerin})$ as function of sinking velocity times the bead's diameter. X-Error bars are +/-$\Delta(W\times D)$, y-Error bars are +/- ΔF_{drag}

c. According to Stokes' law, $F_{Drag}=3\pi\mu DW$ (where D is diameter and W the sinking velocity). Divide the slope you got above (for the regression line) by 3π to obtain an estimate of the viscosity of glycerin (μ). How does it compare with published values (Feel free to use the WWW. Notice that the viscosity of glycerin is a function of temperature)

We find $3\pi\mu=15.44$ (based on the slope of the graph) → $\mu=15.44/3\pi=1.64$Kg/s/m. This is close to values of about 1.42 Kg/s/m reported for glycerin at 20ºC (http://physics.info/viscosity/). The agreement is good and a little surprising given that the Reynolds numbers for the beads are not very small for Stokes law to be strictly applicable.

2. Choose two organisms, one whose swimming is associated with low Reynolds number and the other with high Reynolds number. Describe how their swimming strategies and morphologies match the flow regimes they operate in (20/100).
For each organism, use and cite at least one reference (WWW sources are OK; try Google Scholar) that discusses its swimming.

See reading materials.

3. (20/100) Based on the movie ‘low Reynolds number flow’:

a. What high Reynolds number swimming strategy fails at low Reynolds number?

Symmetric paddling will fail at low Reynolds number. The recovery stroke will exactly cancel the initial stroke bringing the body back to where it started.

b. How are falling (or rising) particles affected by the presence of walls and adjacent particles near them?

Yes. The sinking (or rising speed) is slowed down relative to the case with no walls or high particle concentration.

c. What is reversibility and how is it related to low Reynolds number flows?

Reversibility refers to the property of a flow that is reversed by reversing the direction of time (if F(t) causes u(t) than F(-t) causes u(-t)). This is a property of low Reynolds number flows where inertia is negligible and hence opposite forces result in exactly opposite effects. A consequence is that if you film such flow and then look at it playing it back in time both makes sense, unlike, for example, a jet coming out/in of a spout).
