ASSIGNMENT – SETTLING/CENTRIFUGE/CYCLONE

1.	In a sedimentation process, at low concentration, the particles are settling too fast; what can be changed in order to reduce the speed of the process? A gravity-settling chamber is used to separate large particles from an air-stream before it reaches a filter. In the process, the filter is clogged frequently. What can be the reasons – and what can be done against it? Which dimensionless numbers describe particles in a fluid? Give three, and explain their meaning in terms of ratios of forces (or ratio of another quantity if you prefer).	3
2.a	From a one-particle settling-test: Given are the experimentally determined settling velocity $v_s = 0.0024\text{m/s}$, the liquid viscosity $\eta = 1.5 \cdot 10^{-4}\,\text{kg/sm}$, the fluid density $\rho_f = 1.1 \cdot 10^3\,\text{kg/m}^3$, the solid density $\rho_s = 2.4 \cdot 10^3\,\text{kg/m}^3$, and g=10m/s^2. Compute the equivalent settling diameter x, that is the diameter a sphere should have with these material parameters, assuming laminar (Stokes) flow. Is the laminar assumption consistent with the result?	3
2.b	Perform the same x-calculation with particles that fall ten times (or 100 times) faster. In which flow regimes are these particle types?	2
2.c	Write down force equilibrium (symbols/formulas, no numbers) between gravity, buoyancy, and drag in the case of the terminal settling velocity (no acceleration). Extract the drag coefficient from this equation. Compute the (constant) dimensionless number that does not contain the size (combine Re and C_D such that the size disappears). Relate (for the above values 2.a) the drag coefficient to the empirical drag coefficient given by the relation $C_D = \frac{24}{\text{Re}} + 0.44$, with the Reynolds number $\text{Re} = \frac{\rho_f x v_s}{\eta}$. Obtain an expression for x in the Stokes limit (analytical) and solve the problem graphical for arbitrary Re.	3
3.	Assume particles in a cyclone with drag-, buoyancy-, gravity- and centrifugal forces. Write down force equilibrium and draw the directions of forces. Find for a cyclone of outer radius R=3m, height h=12m, operating with air and particles of density 2100 kg/m^3, the size of those particles that reach the inner diameter r=0.2m, when inlet area 0.6 m^2 and inlet velocity v_I=12m/s are used.	3
4.	Explain the effect of the concentration on the settling velocity of a suspension of particles. You can use a schematic graph. Explain the differences between ideal and real (large systems) conditions. What is the difference between superficial velocity and actual velocity (of fluid/particles)?	3
5.	Sedimentation in a centrifuge is described by the formula $r/r_0 = \exp\left(v_s \omega^2 t/g\right)$, where r gives the position of a particle at time t, with initial position r_0 and angular velocity ω of the centrifuge. Write down the equation of motion for a particle in the centrifuge. Derive the above sedimentation formula from the force-equilibrium in a liquid centrifuge for small particles with negligible accelerations. Explain with a schematic graph how the particle position changes with time.	3