

**TEST EXAM FTV1 – RUG
JUNE 2016**

Maximum # points for each question are indicated

Question 1

Consider a tank of volume V , completely filled, well-stirred and with an inlet and an outlet and a volumetric inflow of ϕ_v . The system is at steady-state.

The incoming water contains component A , with concentration c_A . At time $t=0$, the inflow is switched from component A to B , with concentration $c_{B,in}$.

A) Give the mass balances for component A and B . **5**

B) Show that the sum of concentrations of A and B is constant over time. **10**

C) If $V=10 \text{ dm}^3$ and $\phi_v 1 \text{ dm}^3/\text{s}$, how long does it take before the concentration of A equals that of B ? **10**

Question 2

Lake Geneva's famous fountain produces a water jet stream vertically into the air to a height of 140 m. The cross-sectional area of the (vertical) pipe at the base of the fountain is $0,036 \text{ m}^2$ and the water leaves the pipe at a velocity of 108 km/hr. The pump is located directly underneath the water surface. Friction losses can all be ignored and consider steady-state conditions. Make a drawing of the situation and clearly indicate possible reference points!

Density of water: $\rho=10^3 \text{ kg}\cdot\text{m}^{-3}$; $g=10 \text{ m}\cdot\text{s}^{-2}$.

A) Calculate the power of the pump. **10**

B) What is the pressure directly after the pump? **10**

C) What height reaches the fountain if the cross sectional area of the pipe at the base is reduced to $0,018 \text{ m}^2$? **10**

Question 3

Consider stirring in a closed reactor vessel filled with water. At a rotational speed of 400 s^{-1} the flow regime changes from laminar to turbulent. This so-called critical rotational speed (n_{cr}) for inducing turbulent flow is a function of the density (ρ) and viscosity (η) of the fluid and the diameter (D) of the vessel.

Density of water: $\rho=10^3 \text{ kg.m}^{-3}$; Viscosity of water: $\eta=10^{-3} \text{ kg.m}^{-1}.\text{s}^{-1}$.

A) Derive the dimensionless group containing n_{cr} , ρ , η and D . **10**

We repeat the experiment with a geometrically similar but twice as large vessel and with the vessel filled with a different fluid. It turns out that n_{cr} remains the same.

B) What is the numerical value of ρ/η of the fluid? **10**

Question 4

A spherical bead (diameter $d=10 \text{ mm}$) is dropped into a large volume of glycerol. Almost immediately the bead reaches a constant but very low fall velocity due to the high viscosity of glycerol.

Density of glycerol: $\rho=1260 \text{ kg.m}^{-3}$; Viscosity of glycerol: $\eta=1,5 \text{ kg.m}^{-1}.\text{s}^{-1}$,
 $g=10 \text{ m.s}^{-2}$

A) Write down the force balance for the system. **10**

B) Calculate the velocity of the bead given a density *difference* between bead and glycerol of 270 kg.m^3 . **15**

Question 5

Imagine a flat surface covered with a homogeneous layer of salt of thickness ε . In order to dissolve the salt, the surface is placed in a well-stirred large volume of water.

Because of the large volume the concentration of the salt in the bulk water can be considered to remain zero. The time needed to completely dissolve the salt layer is τ . Assume steady-state conditions.

A) Write down a mass balance for the layer of salt and derive an expression for the layer thickness over time. **15**

Despite the solution is well stirred, adjacent to salted-surface is a boundary layer of thickness δ . The maximal solubility of the salt in water is c_s .

B) If assumed steady-state conditions in the boundary layer, derive the concentration profile of the salt across the boundary layer. **10**

Final mark = total # points / 12,5