

**Exam FTV1-RUG****June 27<sup>th</sup>, 2014****Number of point for each question is indicated****Exercise 1**

The Reynolds number plays an important role in the hydrodynamic behavior of a medium (gas or fluid) flowing around an obstacle. The velocity of the medium is a function of the density and viscosity of the particular medium and a characteristic length, e.g. the obstacle diameter.  $1 \text{ N} = 1 \text{ kg}\cdot\text{m}/\text{s}^2$

**A)** Establish by dimensional analysis the expression for the Reynolds number. **10**

Suppose an oil company is interested in the behavior of oil that encounters an obstacle in the pipe it is flowing through. Because of cost reduction and environmental issues they decide to start out with a pilot experiment in a wind tunnel using a scale model air : oil=1 : 5.

**B)** Given an oil pipe diameter of 1 m and a volumetric oil flow of  $1.57 \text{ m}^3/\text{s}$ , what air velocity should be used in the wind tunnel experiments? **10**

$$\text{oil: } \eta=10^{-2} \text{ Ns}/\text{m}^2$$

$$\text{oil } \rho=0,8\cdot 10^3 \text{ kg}/\text{m}^3$$

$$\text{air: } \eta=1,8\cdot 10^{-5} \text{ Ns}/\text{m}^2$$

$$\text{air: } \rho=1,2 \text{ kg}/\text{m}^3$$

**C)** During the wind tunnel experiment, the volumetric air flow is  $0.2 \text{ m}^3/\text{s}$  while the power loss of the air flowing around the obstacle is 500 Watt. Calculate the pressure drop over the obstacle given the air is blown in horizontal direction? The viscosity of air can in this case be neglected. **10**

## Exercise 2

Water needs to be pumped from an open vessel A to an open vessel B. The total (horizontal) distance between A and B is 21.5 m (see figure). The total height difference that needs to be bridged is 5 m. Vessel B is placed on a balance (in red) to follow the filling process.

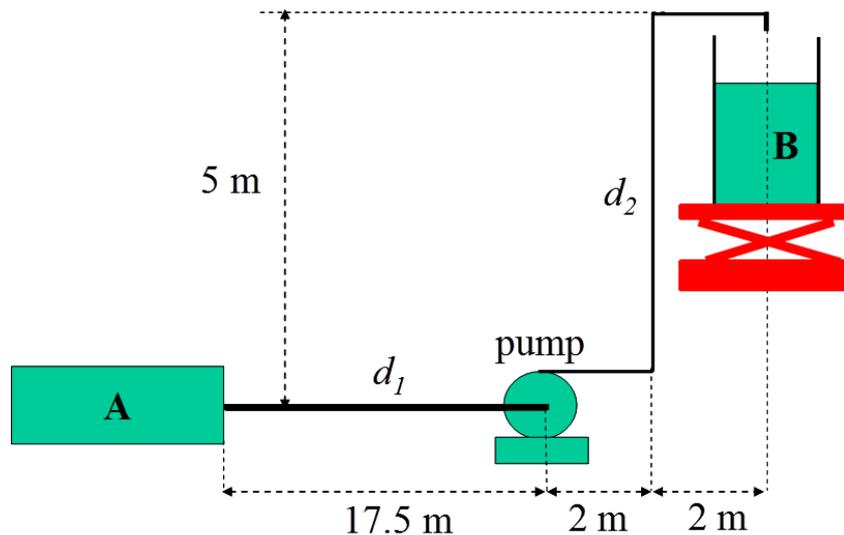
The tubing leading to the pump has a diameter  $d_1$  of =5 cm whereas the tubing leading away from the pump has a diameter  $d_2$  of =2 cm. The fluid velocity ( $v_2$ ) in the tubing leading to vessel B is 5.0 m/s. The water stream enters vessel B in vertical direction.

The apparent height difference introduced by the pump can be ignored and the pressure at the beginning of tubing  $d_1$  might be assumed to be atmospheric.

Tubing is smooth and cylindrically-shaped.  $K_w$  of a  $90^\circ$  bend is 0.5.

For water:  $\eta=10^{-3}$  Ns/m<sup>2</sup>;  $\rho=10^3$  kg/m<sup>3</sup>.

Important: indicate your reference points clearly!



- A) Calculate the pump power needed. 10
- B) Calculate the pressure directly after the pump. 10
- C) What force (weight) indicates the balance at the moment the vessel is filled with exactly 10 liters of water? 10

### Exercise 3

Consider two connected well-stirred containers  $V_1$  of  $10 \text{ m}^3$  and  $V_2$  of  $40 \text{ m}^3$ . Water is pumped from  $V_1$  to  $V_2$  at a rate of  $0.5 \text{ m}^3/\text{s}$ , and back to  $V_1$  (it's a closed system). At  $t=0$ , the temperature in  $V_1$  is  $80 \text{ }^\circ\text{C}$  and in  $V_2$   $30 \text{ }^\circ\text{C}$ .

Both containers contain a heating element,  $V_1$  one of  $1 \text{ kW}$  and  $V_2$  one of  $5 \text{ kW}$ .

Both containers remain completely filled and the volume of the connecting tubes can be neglected as well as the possible heat loss by the tubes to the environment. The ambient temperature is  $20 \text{ }^\circ\text{C}$ .

Hint: starting with the general expression of a balance, remember that in case of a heat balance  $X$  is substituted by  $\rho c_p T$

For water:  $\eta=10^{-3} \text{ Ns/m}^2$ ;  $\rho=10^3 \text{ kg/m}^3$  and  $c_p=4.2 \cdot 10^3 \text{ J/kgK}$ .

- A)** Ignoring any heat exchange with the environment and with the heating elements turned off, what is the final (steady-state) temperature in each container? **10**
- B)** Show that at steady-state the temperature in both containers is the same. **10**

In real practice we cannot of course ignore heat loss due to exchange with the environment. Suppose we now turn on both heating elements and after a certain time the steady-state temperature in both containers becomes  $32 \text{ }^\circ\text{C}$ .

- C)** Given a total surface area available for heat exchange of  $5 \text{ m}^2$ , calculate the overall heat transfer coefficient (in  $\text{W/m}^2\text{K}$ ). **10**
- D)** Show that a same steady-state temperature in both containers (as in C) implies that the heat production in each container exactly balances the heat loss by that same container. **10**

**Grade = (total number of points) / 10**