tentamen ta3220: Fluid flow, heat and mass transfer

9.00-12.00 uur, 25 January 2006, TA Gebouw

There are 4 questions in 2 pages, with a total mark of 60. Please read and understand each question well, before you prepare the answers.

Question 1 - Gas-liquid flow *(20 marks)*

Liquid and (compressed) gas are flowing through a straight, smooth, horizontal pipe with a length of 500 m and a diameter of 4.50 cm. The flow-rates of the two phases are identical: 4.00 m^3/h for the liquid and 4.00 m^3/h for the gas. Calculate the two-phase pressure drop (expressed in *bar*) using the method of Lockhart and Martinelli.

Further data:
Specific mass liquid: 760 kg/m^3
Specific mass gas: 3.80 kg/m^3
Dynamic viscosity liquid: 0.00340 Pa.s
Dynamic viscosity gas: 0.0000170 Pa.s

In case it is necessary to calculate a friction factor for turbulent flow, use the Blasius equation: $f = 0.0791\ Re^{-1/4}$.

Question 2 - Heat loss from a pipe by convection and radiation *(15 marks)*

Common practice in chemical processing plant is to clad (cover) pipe insulation with a durable and thick aluminium foil. The functions of the foil are to confine the insulation layers and to reduce the heat loss to the surroundings by radiation. Because of the presence of chlorine at chlorine plant or a seaside plant for example in Rotterdam harbour areas, the aluminium foil surface (which is initially bright) becomes etched with in-service time. Typically the emissivity of the surface may change from 0.12 at installation to 0.36 with extended service.

For a 300 mm diameter foil-covered horizontal pipe at a surface temperature of 90°C, will this increase in emissivity from 0.12 to 0.36 due to degradation of the foil surface have a significant effect on the heat loss from the pipe (including both convection and radiation)? Consider two cases with surroundings and ambient air at 25°C:

(1) Still air (free convection)
(2) A cross wind velocity of 10 m/s (forced convection)
(3) Compare the relative importance of convection and radiation under above two conditions.

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Question 3 - Transient heat Flow: heat treatment of steel rod *(15 marks)*

Steel rods of 0.05 m in diameter are heat treated by being passed through a heat treatment furnace in which the atmosphere is at 700°C. If the furnace is 5 m in length and the rods enter at 50°C, at what speed must they pass through the furnace to reach 600°C when they leave the furnace? Please check the validity of your approach.

The effective heat transfer coefficient (including convection and radiation) on the rod surface is 135 W/m^2K. The thermophysical properties of the steel are as follows:

Density:	$\rho=7800\ kg/m^3$
Specific heat:	$C_p=473\ J/kg\cdot K$
Thermal conductivity:	$k=41\ W/m\cdot K$

Question 4 - Hydrogen diffusion through a composite metal wall *(10 marks)*

A composite foil made of metal A bonded to metal B, each 0.01 cm thick, is subjected to 0.5 atm of pure hydrogen on metal A's face. The other side (metal B's face) is subjected to a perfect vacuum). At the temperature of interest and 1 atm of hydrogen, the solubility of hydrogen in metal A is 4×10^{-4} g per cm^3 of A and in B it is 1×10^{-4} g per cm^3 of B. It is also known that hydrogen diffuses 4 times as fast in A as in B ($D_{H\text{-}A} = 4D_{H\text{-}B}$), and that A and B do not diffuse in each other.

Please calculate the surface concentration of hydrogen on metal A and metal B, and the interface concentrations between A and B, under steady-state condition.
