Homework N^o 3: multiphase flow transport systems

a.

A mixture of oil and natural gas is to be transported along a pipeline (diameter $D = 0.5\ m$, length $L = 6\ km$) connecting the oil terminal and the refining plant. Fluid properties are the following:

1. oil: density, $\rho_{oil} = 800\ kg/m^3$, viscosity, $\mu_{oil} = 0.01\ Pa \cdot s$
2. natural gas: density, $\rho_{gas} = 1.8\ kg/m^3$, viscosity, $\mu_{gas} = 1.027 \cdot 10^{-5}\ Pa \cdot s$

and fluid flow rates are $w_{gas} = 0.125\ kg/s$ and $w_{oil} = 108\ kg/s$,

1. use Mandane map to identify the flow regime;
2. use Lockhart-Martinelli correlation, $\phi_L = \phi_L(X)$, to calculate the pressure drop along the pipeline (use Blasius law to calculate the friction factor for gas and liquid).

b.

A pipeline should be designed to transport a gas/liquid two-phase flow inside a plant. The two-phase flow mixture is made of a gas flow rate $w_g = 0.44\ kg/s$ (gas density $\rho_g = 1.4\ kg/m^3$, viscosity $\mu_g = 1.5 \cdot 10^{-5} Pa \cdot s$ at plant conditions) and liquid flow rate $w_L = 29.8\ kg/s$ (liquid density $\rho_l = 950\ kg/m^3$, viscosity $\mu_l = 0.9 \cdot 10^{-3} Pa \cdot s$). A pipeline of diameter $D = 0.2\ m$ is available.

1. Using Mandane map, identify which is the flow regime for the mixture if the pipeline already available is used for the transport;
2. Discuss pros and cons of the choice (is it better to use a larger/smaller pipe?);
3. Use Lockhart-Martinelli correlation to calculate the pressure loss if the length of the pipeline chosen ($D = 0.2\ m$ or any other selected diameter) is $L = 50\ m$ (use Blasius friction factor to calculate the pressure drop for the liquid and gas alone).
4. Calculate the pressure drop along the last part of the pipeline (vertical duct, $\Delta H = 2\ m$).

c.

Calculate the pressure drop along an horizontal duct used for the pneumatic conveying of carbon particles. Problem data are summarized in the following Table.

Physical properties of carrier gas			
Molecular weight	MM	28.9	$[kg/kmol]$
Pressure	p	$1.0 \cdot 10^5$	$[Pa]$
Temperature	T	288	$[K]$
Viscosity	μ	$1.80 \cdot 10^{-5}$	$[Pa \cdot s]$
Density	ρ	1.21	$[kg/m^3]$
Physical properties of suspended phase			
Density	ρ_p	1400	$[kg/m^3]$
Diameter	D_p	$2.90 \cdot 10^{-4}$	$[m]$
Pipeline geometrical characteristics			
Length	L	1.5	$[m]$
Diameter	D	$2.30 \cdot 10^{-2}$	$[m]$
Area	A	$4.15 \cdot 10^{-4}$	$[m2]$
Flowrates			
Fluid	W_g	0.03	$[kg/s]$
Particles	W_s	0.58	$[kg/s]$

d.

Hot air ($\dot{m}_{air} = 107,000\ Nm^3/h$, $T = 60C$, $MM = 29\ kg/kmole$, $\mu = 1.8 \cdot 10^{-5} Pa \cdot s$) is used to transfer wood fiber ($\dot{m}_{fiber} = 27660\ kg/h$, $\rho_{fiber} = 350\ kg/m^3$, $d_{p,eq} = 2\ mm$). along an horizontal line ($L = 170\ m$, $D = 1.3\ m$)

1. Check if the transport of fibers is in the dilute regime;
2. Calculate the pressure drop along the line;
3. Due to changes in the plant layout, four 90^o bends (curvature radius, $R = 5\ D$) need to be inserted at the end of the line. Calculate the additional pressure drops due to the bends (use Figure 11 from "Introduction to the theoretical and practical principles of pneumatic Conveying" to estimate the extra length of the pipe associated to the presence of the bend).