Department of Material Science and Engineering
Faculty of Natural Science
NTNU

NTNU

Exercise 5: TMT4208

Hand out: 08.02.2021
Seminar: 12.02.2021
Hand in: 19.02.2021

Task 1: Reacting flows

a. Describe the governing equations for reactive flows within a single phase perspective.

b. How would you proceed to describe reactive flows in a *multiphase* perspective?

c. Given the (assumed) elementary reaction

$$2\text{A} + 3\text{B} \rightarrow \text{C} \tag{1}$$

- **i.** Describe the reaction rate for the reaction.
- **ii.** What is the order of this reaction and the units of the rate constant?

Task 2: Terminal velocities

a. In the lecture notes, we have described drag coefficients for spherical particles under different flow regimes, based on the Reynolds number of the particle, which in turn depends upon the velocity. How would you resolve this *chicken-egg* situation in practical calculations?

b. Calculate the terminal velocity for a 20 μm diameter (spherical) solid inclusion with $\rho_p = 2.7 \cdot 10^3$ kg/m^3 in a stagnant steel melt with $\rho = 7.1 \cdot 10^3$ kg/m^3 and $\mu = 5.5 \cdot 10^{-3}$ Pa·s.

c. Calculate the terminal velocity for a 5 mm diameter (spherical) ash particle with $\rho_p = 2.7 \cdot 10^3$ kg/m^3 in air with $\rho = 1.2$ kg/m^3 and viscosity $\mu = 2 \cdot 10^{-5}$ Pa·s. Would your results change if the viscosity was (significantly) different?

d. Using the diagram presented in figure 2, estimate the terminal velocity and shape of a 8 mm air bubble with density $\rho_b = 1.2$ kg/m^3, rising in:

- **i.** Water at 20^{o}C with density $\rho = 1.0 \cdot 10^3$ kg/m^3, viscosity $\mu = 1 \cdot 10^{-3}$ Pa·s and interfacial tension 0.073 N/m.
- **ii.** Molten steel at 1600^{o}C with density $\rho = 7.5 \cdot 10^3$ kg/m^3, viscosity $\mu = 6.1 \cdot 10^{-3}$ Pa·s and interfacial tension 1.5 N/m.

Task 3: Flow through a packed bed

As a part of an experimental campaign in which the burden of a blast furnace is to be optimized, the pressure drop Δp was measured over a packed bed of (unequal) samples of charge materials, coke and sinter in a laboratory apparatus. Air at 20^{o}C, with density $\rho = 1.2$kg/m^3 and viscosity $\mu = 1.82 \cdot 10^{-5}$ Pa·s was blown through a vertical pipe (shaft) filled with relevant samples and Δp over the bed height L was recorded as a function of air velocity u_0 in reference to the empty shaft - as sketched in figure 1a. The resulting experimental data is given in figure 1b, showing a linear trend between $\Delta p/Lu_0$ and u_0.

Determine the average particle size of the charge material as well as the void fraction of the packed bed.

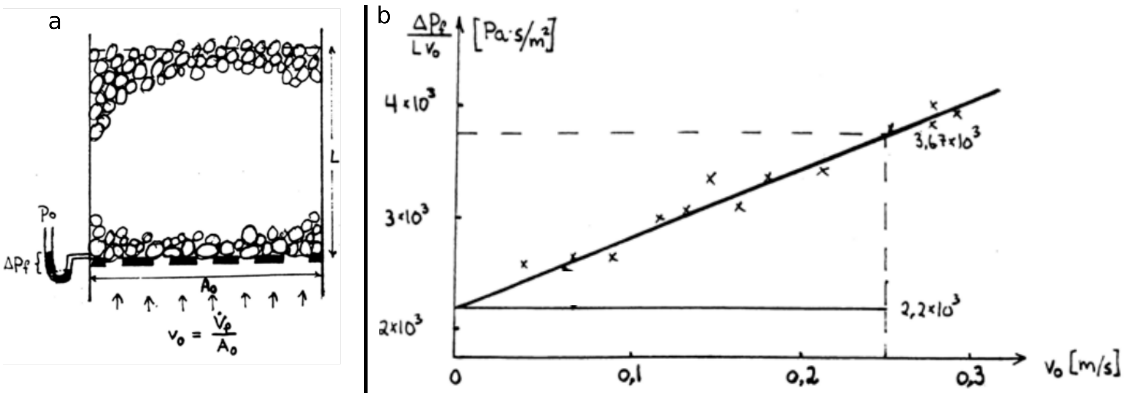

Figure 1: Sketch of experimental setup (a) and experimental results (b).

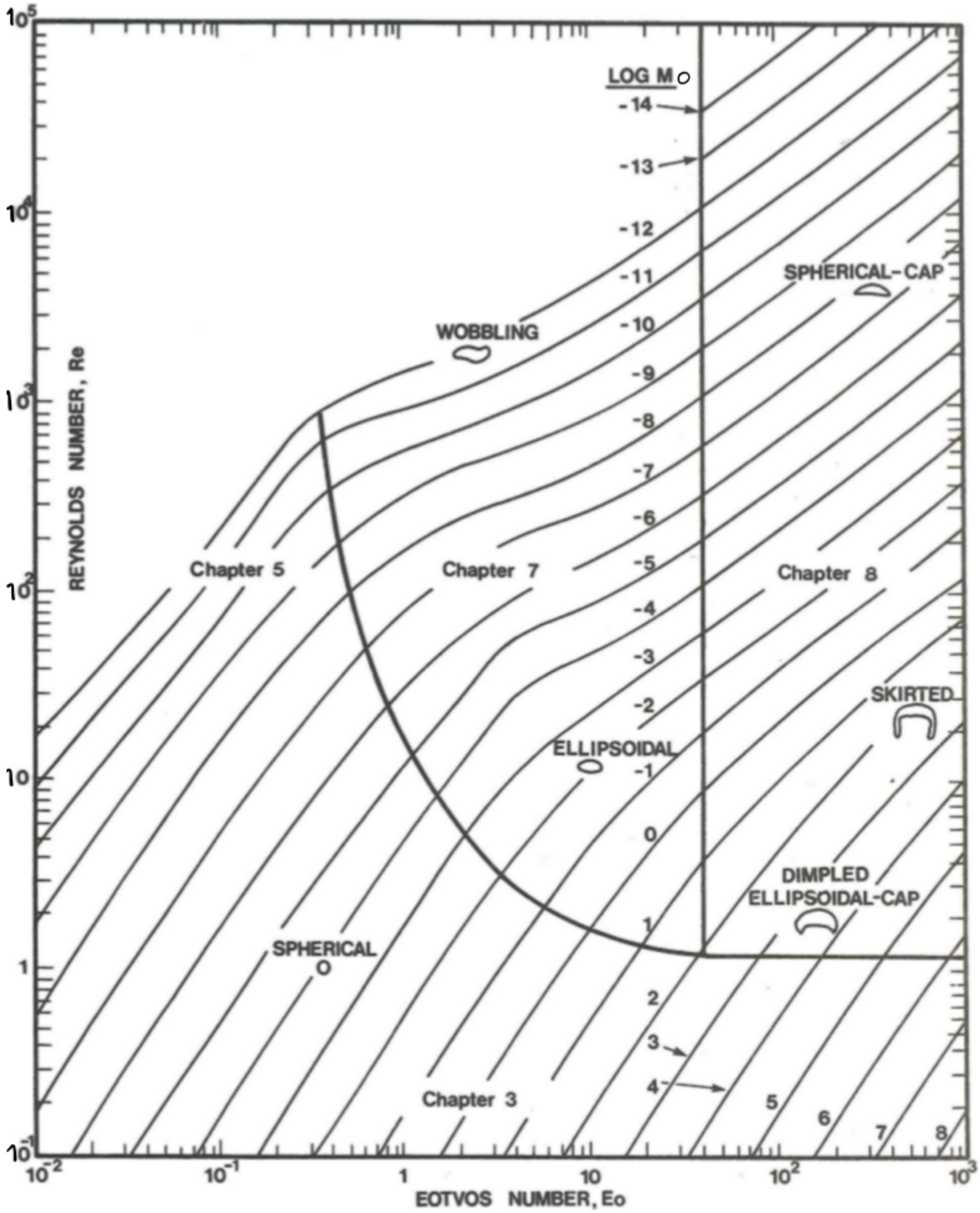

Figure 2: Shape regimes for bubbles and drops in unhidered gravitational motion through liquids as of Clift et al. *Bubbles, Drops & Particles.*