

All material is allowed, but only individual work. You should be able to solve all questions with a normal calculator or Excel and by using course material only. Using results from any simulation software are not accepted; you need to show how the calculation was done. If you use Excel, the worksheet is not sufficient for an answer, but written text is required. Written texts should be returned to a Turnitin -box, others to the assigned folders.

Maximum 5 points from each question.

You can also give additional feedback related to the whole course; in case of constructive feedback (potentially leading to improvements), additional point may be given. Please upload your feedback as a separate document.

1. You are standing in a corridor with another person, who sneezes. Describe in words how would you design your location with respect to the other person so that you would be safe if the droplets or aerosols released during sneezing may contain harmful ingredients. Describe relevant variables to be taken into account and explain in more detail at least three relevant fluid flow related terms. The total description length should be one page at maximum.
2. Derive an equation for permeability in a packed bed with known particle sizes and void fraction. How does the equation change if flow is slow (laminar)? Hint: use definition of permeability and Ergun's equation.
3. A stirred bioreactor should be scaled up from laboratory experiments in order to produce viral vaccine. In the lab, it is found that good productivity, mass transfer and negligible cell damage was obtained with cylindrical vessel of 4 liters broth volume, with broth height equal to vessel diameter. Impeller speed was 400 rpm and its diameter is 1/3 of the vessel diameter. Is the reactor turbulent if broth properties are those of water, or if viscosity of the broth is 20 times larger?

Your task is to design a 1 m³ reactor with the same geometry and power/broth mass ratio in order to keep the same gas-liquid mass transfer rate.

- a) How much mixing power is needed, if impeller Power number is 5?
- b) What should be the impeller speed (rev/min)?
- c) If air is fed from the bottom of the tank with 0.1 VVM (volumes of vessel per minute, calculated based on broth volume), how much air is needed and how much power is put in through gassing? You can neglect air density change due to the hydrostatic pressure.