Soft Matter course MSE-425, Fall 2025
Challenges

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Deliverable:
Presentation: maximum 10 min + 5 min questions, each team member must present a part. Presentations will take place on the 11.12. and 18.12.2025.

Note that do you NOT need to hand in any report

Grading of the challenge accounts for 25% to the total grade

Points considered for the grading:

- Content
  - Are facts correctly presented?
  - Is the solution appropriate?
  - Creativity. Are the explanations sufficient to understand the underlying principles and did you think of a new idea?
- Presentation
  - How is the content presented and explained?
  - Is a proper terminology used?
  - Are appropriate and illustrative figures used?
  - Are figures correctly referenced?

The same grade will be given to the entire group.

Teams
2-4 students per group. Please fill in the google doc: Challenges will be given on a first come first serve basis.

Tasks

1 Liquid crystal display

Task: You work in a company that develops nematic liquid crystal TVs. You would like to convince your boss that ferroelectric liquid crystals are better. To convey your message, address the following questions:

- What are the advantages of ferroelectric liquid crystal displays compared to nematic liquid crystal displays?
- What are the disadvantages? Are there any possibilities to minimize the impact of these disadvantages?
- How would you design such a liquid crystal display?
- What materials/ molecules would you choose to design such a display and based on what parameters would you choose the material?
- How would you tune the colors?
- What would you do to minimize the energy consumption of the display?
- How would you characterize the alignment of the liquid crystals?

2 Detergents

Task: You work for a company that develops new laundry detergents. You are responsible for the development of sustainable products and would like to introduce a laundry detergent that removes the same amount of dirt with lower concentrations of detergents.

- What detergents would you propose?
- What parameter(s) would you change to reduce the concentration of detergents needed to remove dirt?
- What changes in the detergent structure would you propose to increase the efficiency of the detergent?
- How would you design a detergent that sticks to the cloths and why would that be advantageous?
- How would you characterize this detergent?

3. Espresso

Task: You work for a food company that specializes in producing coffee. You are responsible for the Espresso production and are asked to adjust the formulation of your espresso capsules such that the espresso has a nice, relatively thick layer of a stable foam. To achieve this goal, you work on the formulation of additives contained in the espresso capsules. You realize that with your current formulation, you form a thin layer of foam on top of the espresso but the foam disappears within seconds.

- Why do you think the foam disappears so quickly?
- What would you do to prolong the lifetime of the foam and why?
- What do you expect to happen with the foam if you add sugar and/or milk?

4. Coffee

Task: You work for a food company and are responsible for the coffee. You realized that your customers wish to consume caffeine but they do not like the taste of it because it is bitter. You are asked to develop a coffee powder that contains the same amount of caffeine as your current formulation. However, to mask the taste of caffeine, you want to encapsulate the caffeine and only release it in the stomach. Caffeine is moderately soluble in cold water and well soluble in boiling water. Capsules should be

7. food grade
8. smaller than 5 µm in diameter to minimize the risk that the tongue can sense them
9. impermeable to caffeine during storage and the preparation of the coffee
10. they should not aggregate if dispersed in water
11. they should release caffeine either in the stomach (pH = 2) or in the intestine (pH = 6).

- What types of capsules would you suggest to use and why?
- What material(s) would you choose to make the capsules from?
- How do you ensure that caffeine is retained in the capsules during storage?
- How would you maximize the loading of caffeine?
- How would you characterize the capsules?

5. Ketchup

Task: You work for a food company that produces ketchup. They decided to improve the flow behavior of ketchup because customers complain that the ketchup is too much shear thinning such that it tends to spill. As a result, a lot of Ketchup is wasted. The company decided to tackle this problem in two ways: They built a team that re-designs the bottle and one team that tests different formulations of the ketchup to reduce the shear thinning behavior. You are heading the second team. To re-formulate the ketchup, you would like to understand the reason for the shear thinning behavior and subsequently to adjust the formulation.

- What are the main components of ketchup?
- How would you reduce the shear thinning behavior of Ketchup?
- How would you change the processing of ketchup to implement your ideas?
- Do the changes influence the taste of ketchup?

6. Cheese

Task: You work for a dairy company and are asked to develop a new type of cheese with a high E-modulus that only melts at elevated temperatures.

- Describe the different stages of the transformation of milk into cheese.
- How can you tune the shear modulus of cheese?
- What happens on a microscopic level, if cheese melts?
- Can you tune the melting point of cheese? If yes, why, if not, why not?

The company is happy with your most recent developments and asks you to design another cheese that has a low E-modulus and melts already at temperatures only slightly above body temperature.

- What would you change in your cheese formulation?

- How would these changes affect the E-modulus of cheese?
- Would these changes affect the processing of the cheese?

7. Mayonnaise

Task: You work for a food company that produces mayonnaise. You would like to reduce the amount of oil contained in mayonnaise.

- How do you make mayonnaise
- How do you ensure the mayonnaise remains homogeneous to the eye even if stored for a prolonged time?
- How could you reduce the amount of oil contained in mayonnaise?

8. Chocolate

Task: You work for a food company that produces chocolate. The company asks you to design a chocolate that is conceived as homogeneous by our eyes. The chocolate should melt at 37°C.

- What are the main ingredients of chocolate?
- What would you do to ensure the chocolate is optically conceived as homogeneous?

You realize that your new chocolate fulfills all the requirements but with time, the dark chocolate starts to become gray at the surface while the white chocolate does not.

- Why could that be?
- What could you do to delay this change in color?

9. Holographic chocolate

Task: You are working for a confectionery that would like to introduce chocolate, which becomes colorful if illuminated with light without using any chemical additives.

- What strategy would you propose to introduce color? Explain the concept behind your idea.
- How would you process the chocolate to achieve the coloring effect?
- How would you make sure the coloring of your chocolate does not influence its taste?
- How would the coloring of your chocolate affect its price?

10. Chocolate mousse

Task: You work for a food company that develops powders to make chocolate mousse. Your current formulation results in a chocolate mousse that is dense. You are asked to change this formulation to make a chocolate mousse that contains a high concentration of pores to decrease its density and hence, the volume-normalized calories.

- What would you add to your formulation to increase the density of pores in the chocolate mousse?
- How would you control the size of the air bubbles?
- You realize that the air bubbles coalesce during the processing of the chocolate mousse. What would you change to ensure air bubbles do not coalesce during processing?

- What would you do to ensure air bubbles remain stable for at least 12 h if stored at 4°C?

11. Meringues

Task: You are owning a catering company and are developing new formulations for meringues. To do so, you would like to understand how the standard formulations work.

- How do you produce meringues?
- How do you stabilize the foam?
- You realize that if you spill some yolk, the foam is much denser. Why is this the case?
- Why do you have to bake the meringues to solidify them?
- You would like to add some additional taste makers to the meringue. What parameters do you have to consider to ensure that you still obtain a foamy, porous meringue?

12. Ouzo

Task: Ouzo is, in essence, a mixture of water, ethanol, and some anethole oils. Fresh Ouzo is transparent. However, upon addition of ice, it turns turbid.

- Why does Ouzo turn turbid upon addition of ice?
- What could you do to prevent this turbidity even if you add some ice?
- How does the temperature influence the appearance of Ouzo?

13. Gluten-Free Bread

Task: You work for a food company that wants to expand its market by introducing gluten-free products. You are asked to develop a product that resembles wheat bread's texture, taste and aroma.

- What are the main components of bread? How is bread produced?
- What is the role of gluten in bread? What is the role of temperature during the bread making process?
- Suggest a recipe for gluten-free bread explaining the role played by each component.
- How could you characterize the mechanical properties of gluten-free bread to compare them with wheat bread, and what would you expect as results?

14. Beer Foam

Task: You work for an international beer company. You are in charge of the development of a new beer whose foam has to reach certain characteristics.

- What are the main components of beer?
- How is beer produced?
- How is the beer foam created?
- How can you stabilize foam and how do you characterize it?
- You are asked to develop a beer that creates a thick layer of foam, which is stable for several minutes. Please, make a suggestion for a recipe. Explain the role of each of the components you suggest.

15. Synthetic Lung Surfactant

Task: You work for a pharmaceutical company that wants to develop a new medicine for people suffering of pulmonary disorders.

- What is a lung surfactant and which are its main characteristics?
- Propose a product that resembles the natural lung surfactant. How would you characterize it?
- What are the parameters you would optimize to maximize the efficacy of the treatment?
- How would you tune the rheological properties of your product?

16. Magnetic resonance imaging (MRI) contrast agents

Task: You work for a diagnostic company that develops a new generation of iron oxide nanoparticle-based MRI contrast agents. These contrast agents should

1. have an iron oxide core about 20 nm in diameter and
2. be stable in aqueous solutions under physiologic conditions (high salt concentrations, pH = 7.4, T = 37°C)

- What would you do to ensure that these particles can easily be dispersed in aqueous solutions and how would you do it?
- What materials would you use to modify their surfaces and why?
- How would you ensure that nanoparticles remain stable if dispersed in aqueous solutions over time, even if strongly diluted?
- How would you characterize the nanoparticles?

17. Wound dressing

Task: You work for a biomedical company that asks you to develop a material suited for moistening wounds and protecting them. The material should

1. be biocompatible
2. be antimicrobial
3. absorb a high quantity of fluids that are excreted from the wound
4. be permeable to water.

- What type of material would you choose?
- How would you process this material?
- How would you tune the permeability of the material?
- How would you tune the mechanical properties of the material?
- How would you decrease the risk for bacterial infections?

18. Contact lenses

Task: You work for a company that fabricates contact lenses. You are asked to design contact lenses that should

1. be biocompatible
2. be permeable to O_2
3. be flexible when wet (they can be hard when dry)
4. not degrade over at least 1 year

- What type of material would you choose?
- How would you tune the mechanical properties of the contact lenses?
- How would you tune the optical properties of the lenses?

19. Implant coatings

Task: You work for a biomedical company that develops knee implants. These implants are coated with TiO_2. You are asked to develop a coating that prevents the adsorption of proteins and bacteria to minimize the risk for infections. Ideally, the coating should be thin and homogeneous.

- What type of coating would you use?
- How would you deposit the coating (solvent, adsorption conditions etc.)?
- What would you do to obtain a dense coating?
- What would you do to ensure the coating remains stable under physiologic conditions over a prolonged time?
- How would you characterize the thickness, homogeneity, and protein resistance of the modified surface?

20. Medical implants

Task: You are working for a medical company that develops soft implants for humans. The company decided to introduce a new pilot line of soft implants that can easily be customized. Therefore, they would like to 3D print these polymeric implants using an extrusion-based process.

- What type of ink would you suggest? Describe the different ingredients.
- What are the ink parameters you would optimize to maximize the resolution and shape fidelity of the printing?
- How would you tune the mechanical properties of the resulting implant?

21. One component coating

Task: You work for a coating company and are responsible for the development of the next generation of finishers. The finisher the company sold thus far was a two-component system where the two components were mixed immediately prior to their application. When mixed, coatings must be applied within 1 h. Thereafter, they become too viscous and cannot be used any more. To minimize the waste of coatings, you and your team are developing a one-component finisher. You are planning to convert the two-component finisher into one component by encapsulating one reagent and having the second reagent in the surrounding phase. To ensure good stability of the finisher during storage and efficient curing when applied, capsules should be non-permeable to the reagents during storage and release the components if applied with a brush.

- What type of capsule would you suggest to use?
- How would you fabricate the capsules?
- How would you make sure the empty capsules do not deteriorate the quality of the coating?
- How would you make sure the two components are fully mixed such that the finisher is homogeneous and fully polymerized?

22. Car coatings

Task: You work for a car company and are responsible for the development of a new coating, which should be applied using sprays. The finishers are often composed of crosslinked polymers; they are sold as two-component systems that, if mixed, start to react.

- How would you design such a two-component system?

- How would you tune the scratch resistance of the resulting finisher?
- To obtain a high-quality coating, it is important that the finisher does not flow when sprayed. How would you make sure the applied finisher does not flow?
- How would you ensure that the coating strongly adheres to the substrate such that it does not delaminate?

23. Car tires

Task: You work for a company that fabricates car tires. You are asked to design car tires that have a good adhesion at low and high temperatures. You would like to test a model system that consists of one type of material (the main component of the tire), knowing that you have to add additives later on to improve its performance.

- What starting material would you use and how would you process it into car tires?
- How would you tune its adhesion towards roads?
- How would you make sure that its mechanical properties do not change significantly in a temperature range between -10°C and 40°C?

You optimized your material to have a good adhesion. However, you realize that it has a high wear and, thus, this tire must be replaced very often. This makes customers unhappy.

- How would you reduce the wear?
- Would this modification change the adhesion? If yes, why? If not, why not?

24. Solvent sensors

Task: You work for a company that develops sensors. You are asked to design a coating that, if deposited on a substrate, changes its color if immersed into certain solvents. The change in color should be indicative of the type of solvent present.

- What material(s) would you use to form this coating?
- Describe the structure and composition of the individual components of the coating.
- How would you apply the coating?
- How would you tune the color of the coating?
- Why would the coating change its color if infused with different solvents?

25. Bank notes

Task: You are asked to develop bank notes that are difficult to fake because some of the features contained on them change their colors if the banknote is tilted.

- What colorant would you suggest and why?
- How would you tune the color?
- How would you produce these colorants?
- How would you make sure that the color does not fade/come off with time?