UNIVERSITY OF CAMBRIDGE

NATURAL SCIENCES TRIPOS Part II

May–June 2020 **1 hour 15 minutes**

PHYSICS (8)
PHYSICAL SCIENCES: HALF SUBJECT PHYSICS (8)

SOFT CONDENSED MATTER

Candidates offering this paper should attempt a total of ***four*** *questions:* ***three*** *questions from Section A and* ***one*** *question from Section B.*

The approximate number of marks allocated to each question or part of a question is indicated in the right margin. This paper contains ***four*** *sides, including this coversheet. You may use the formula handbook for values of constants and mathematical formulae, which you may quote without proof.*

You have 75 minutes (plus any pre-agreed individual adjustment) to answer this paper. Do not start to read the questions on the subsequent pages of this question paper until the start of the time period.

Please treat this as a closed-book exam and write your answers within the time period. Downloading and uploading times should not be included in the allocated exam time. If you wish to print out the paper, do so in advance. You can pause your work on the exam in case of an external distraction, or delay uploading your work in case of technical problems.

Section A and the chosen section B question should be uploaded as separate pdfs. Please name the files 1234X_Qi.pdf, where 1234X is your examination code and i is the number of the question/section (A or 4 or 5).

STATIONERY REQUIREMENTS
Master coversheet

SPECIAL REQUIREMENTS
Mathematical Formulae handbook
Approved calculator allowed

SECTION A

Attempt ***all*** *questions in this Section. Answers should be concise and relevant formulae may be assumed without proof.*

1 Outline the possible behaviours of non-Newtonian fluids, sketching the possible forms of response to a shear force, giving examples of materials exhibiting each type. [4]

2 At room temperature the Debye-Hückel screening length in 10^{-4} M KCl solution is 30 nm. What is the equivalent distance at this temperature for 10^{-3} M $CaSO_4$? [4]

3 For oil being pushed along a pipe of radius 5 cm, a pressure difference of 150 kPa between the two ends of the pipe is required to achieve a given flow. If the radius is increased to 6 cm, but all other parameters remain the same, what is the pressure drop required to yield the same throughput of oil? [4]

SECTION B

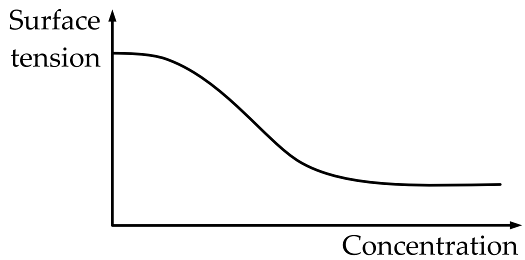
Attempt one question from this section

4 (a) Explain what an amphiphile is and give three examples. [4]

(b) Amphiphiles tend to aggregate into micelles at sufficiently high concentrations. With reference to molecular parameters, discuss the different shapes that form and over what range of parameters. [3]

(c) What is meant by the critical micelle concentration? Discuss the distribution of micelle sizes at different amphiphile concentrations. [4]

(d) At the air-water surface, surfactant molecules can aggregate, affecting the surface tension. The general form of this behaviour is shown in the diagram below. Discuss why the response has this form. [4]



(e) Given the form of this curve, explain why surfactants can be used to stabilise bubbles and facilitate the formation of bubbles, and how the optimum surfactant concentration should be determined. [4]

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5 (a) Outline the different solubility regimes for a polymer in solution as a function of temperature and interaction parameter χ in terms of the concentration ϕ. Include in your discussion an explanation of the terms good, poor and θ solvent conditions and describe the chain conformation in each case. [6]

(b) Provide a sketch of the different regimes of behaviour. [3]

(c) For polystyrene chains, with a statistical segment length of 0.67 nm and a degree of polymerisation N of 1500, calculate the end-to-end distance R in (i) toluene (good solvent), (ii) water (bad solvent) and (iii) cyclohexane at 34.5°C (the theta temperature). [3]

(d) Define the overlap volume concentration ϕ^* and evaluate it for the case of polystyrene in cyclohexane at 34.5°C. [2]

Within the Flory-Huggins model, the spinodal equation is given by

$$\chi(\phi) = \frac{1}{2}\left(\frac{1}{\phi N} + \frac{1}{1-\phi}\right) .$$

(e) Explain the physical meanings of the spinodal line and the critical point and, within the Flory-Huggins model, obtain an expression for the value of χ at the critical point χ_c. Indicate the relationship of these quantities to your sketch of phase behaviour. [5]