

Exam in Soft Matter Physics TIF015/FIM110

Time: Monday October 17, 2011, 8.30-12.30.

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Allowed material: Physics Handbook or equivalent, dictionary and pocket calculator

Grading: 24 points, is required for a passed.

Review of the exam: Monday November 7, 12-12.30, Signalen (Signes)

Note: All answers must be in English. Motivate all answers carefully. Answers without motivation give no credit.

1. Consider a polymer mixture of molten polyethylene chains $-(CH_2)_n$ with 50% of the chains having a M_w of 10000 and 50% of the chains having a M_w of 20000.

a) Calculate number average, M_n , weight average, M_w , and dispersion. (4p)

b) Sketch the $G(t)$ – the stress relaxation modulus of the two polymer melts mentioned above (mark the curves) with arbitrary units on the axes (OBS now the polymers are not mixed) (3p)

c) $G(t)$ decreases rapidly at the terminal time τ_T which depends strongly on molecular weights (N). Using simple reptation arguments calculate the ratio of τ_T (M_w 10000) to τ_T (M_w 20000) (3p)

2. The distribution of end-to-end vectors (R) in an ensemble of random polymer coils is Gaussian. The Gaussian probability function is:

$$P(\bar{R}) = \left(\frac{2\pi Na^2}{3} \right)^{-3/2} \exp\left(\frac{-3\bar{R}^2}{2Na^2} \right)$$

As can be seen from the function above the probability decreases monotonically with increasing R (one end is attached at origin). The radial distribution $g(R)$ is obtained by multiplying with $4\pi R^2$

a) Sketch (coarsly) $P(R)$ and $g(R)$ assuming chains with $N=10000$ and $a=1 \text{ \AA}$. (4p)

b) Calculate the most probable end to end distance R_{mp} of a Gaussian chain. (6p)

3. The velocity autocorrelation function is defined through

$$Z(t, s) = \langle v(t+s)v(s) \rangle = \lim_{\tau \rightarrow \infty} \frac{1}{\tau} \int_0^\tau v(t+s+t')v(s+t')dt'$$

In equilibrium the correlation function is independent of s , i.e. stationary.

a) Show that the stationary character implies

$$\langle \dot{v}(t)v \rangle = -\langle v(t)\dot{v} \rangle \text{ and hence } \langle \dot{v}v \rangle = 0$$

(v without a time parameter means $v(0)$) (4 p)

Since correlation functions are even functions they can be expanded in even powers of t :

$$Z(t) = Z(0) + \langle \ddot{v}(0)v \rangle \frac{t^2}{2} + \mathcal{O}(t^4)$$

b) Use the result in a) to show that the coefficient of the second order term satisfies

$$\langle \ddot{v}v \rangle = -\langle \dot{v}\dot{v} \rangle = -\langle F^2 \rangle / m^2,$$

thus relating short time velocity correlations to the variance of the average force F exerted on the particle. (4 p)

c) Which material constant is proportional to the time integral of the velocity autocorrelation function, $\int_0^\infty \langle v(t)v \rangle dt$? (2 p)

4. a) Describe the order and structure of the nematic, the smectic A, and the smectic C liquid crystal phases. (3p)

b) Discuss the differences in response times switching from dark to bright and from bright to dark in LCDs (4p)

5. a) Propose a way to determine if a material is amorphous! (2p)

b) Sketch the behaviour of entropy as a function of temperature around the glass transition. How can this behaviour be explained? (4p)

6. A water solution of the amphiphilic molecule SDS ($C_{12}H_{25}-OSO_3Na$) is above the critical micellar concentration. The amphiphilic molecule can be modelled with the critical chain length given by $l_c \approx (0.154 + 0.1265n)$ nm, the hydrocarbon volume given by $v \approx (27.4 + 26.9n) \times 10^{-3}$ nm³, and the optimal head group area $a_0 = 0.65$ nm².

Consider now the solution as a colloidal suspension.

a) As a very crude first approximation the system can be considered as a hard sphere system. Draw a diagram (with units on the two axis) of the interaction potential as a function of distance from the centre of the micelles. (4p)

a) In reality this is not a hard sphere system. Which mechanism do you expect to be dominant in stabilizing this system and how can you destabilize the system? Also sketch the corresponding interaction potential diagram in this case. (3p)

7a) For two or more phases to be in stable equilibrium, the intensive state variables have to be equal in the different phases. Name the three most common ones. (2 p)

b) What should happen to the volume when we increase the pressure of a stable system? What does this imply in terms of the shape of Gibbs free energy around a stable state point? (4 p)

c) Consider a stable mixture of solvent (volume fraction $\phi = 0.6$) and polymer (volume fraction $1 - \phi = 0.4$) with free energy of mixing shown in the figure below. What happens if we add solvent to the mixture? What happens if we remove solvent? (4 p)

