Materials for Devices: Problem Set 4

14. (i) Given that the C−C bond length is 0.154 nm and the C−H bond length is 0.114 nm, estimate the length and width of a linear polyethylene molecule consisting of 1,000 carbon atoms (the tetrahedral bond angle is 109.5°).

    (ii) What is the molecular weight of this molecule?

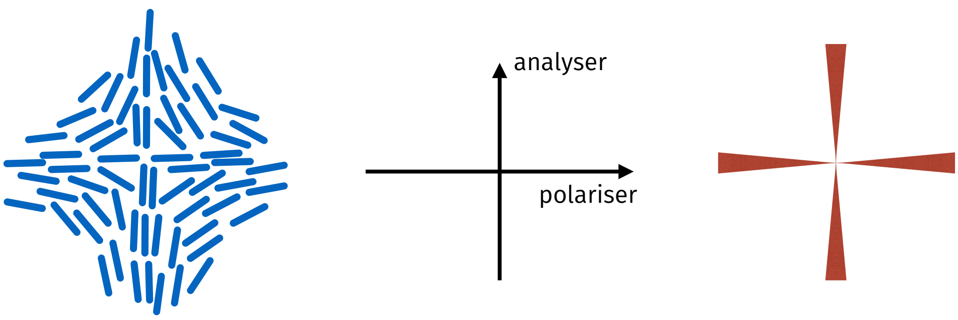
    (iii) What is the end-to-end distance, assuming a completely flexible chain, made up of C−C segments which can twist and rotate completely independently?

    (iv) What is the end-to-end distance using the more reasonable assumption that the Kuhn length is made of 3.5 C−C segments?

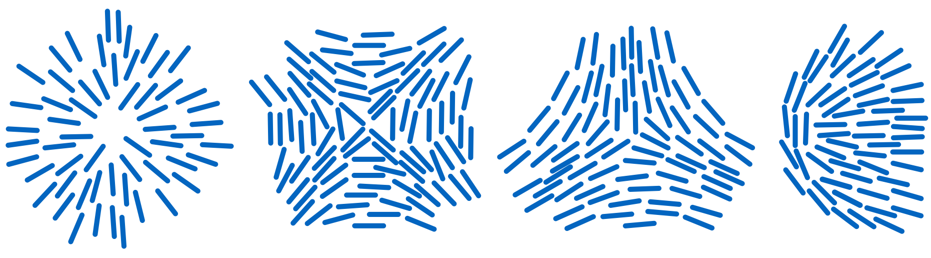
    (v) If this chain were scaled up to the dimensions of a piece of string (e.g. about 2 mm wide), how long would it be? In a scaled-up polymer model, if this piece of string represents a linear polyethylene molecule, what would be the average end-to-end distance in the model?

15. Consider a birefringent material placed between crossed polarisers. Let the optical path difference be OPD $= k\lambda + \frac{\lambda}{2}$ for positive integer k, or equivalently the phase difference is $\delta = 2\pi k + \pi$. Discuss whether light is transmitted in this setup.

16. A nematic liquid crystal, which hosts different director orientation patterns in different regions, is observed between crossed polarisers. The following Figure depicts a the orientation of the rod-like molecules in a particular sample (left) together with its appearance (right) when the crossed polarisers are oriented as shown (centre):



Sketch the patterns that would be observed for the following samples if the crossed polarisers remain in the same orientation as above:



17. A wedge of quartz with a birefringence of 0.009 and an angle of 1° is cut with a permitted vibration direction along its length.

   (i) Describe and explain what will be observed when the wedge is viewed between crossed polars, with its length at 45° to the polariser/analyser, when using sodium light of wavelength $\lambda = 590\,\text{nm}$. What is the distance between dark bands?

   (ii) Describe and explain what happens if the wedge is then rotated so that its length lies parallel with (a) the polariser, and (b) the analyser.

   The quartz wedge is next viewed in white light, and a uniform nematic liquid crystal sample is added to the light path, that is, the quartz wedge is placed on top of the liquid crystal sample and viewed between crossed polars. The long axes of the liquid crystal molecules in this sample, known to correspond to the slow vibration direction of the sample, are oriented parallel to the length of the wedge.

   (iii) A black band is observed on the wedge, 13.6 mm from its tip. Does the length of the wedge correspond to the fast or the slow vibration direction in the quartz sample?

   (iv) What colour would the liquid crystal sample show if the wedge were removed?

   (v) The liquid crystal sample is measured to have a thickness of 0.05 mm. What is its birefringence?