

ENGINEERING TRIPOS PART IIB

Thursday 29 April 2004

2.30 to 4

Module 4B17

PHOTONICS OF MOLECULAR MATERIALS

Answer not more than three questions

All questions carry the same number of marks

*The **approximate** number of marks allocated to each part of a question is indicated in the right margin.*

There are no attachments.

You may not start to read the questions printed on the subsequent pages of this question paper until instructed that you may do so by the Invigilator

(TURN OVER)

1 (a) Comment on the symmetry differences between isotropic liquids and nematic, smectic A and smectic C liquid crystals. [20%]

(b) What is the orientational order parameter of a nematic liquid crystal? Illustrate your answer by considering a very small group of rod-shaped molecules with an order parameter of 0.8. [30%]

(c) The Meier-Meier equation (which relates the dielectric constants of a nematic liquid crystal to molecular properties) is given below.

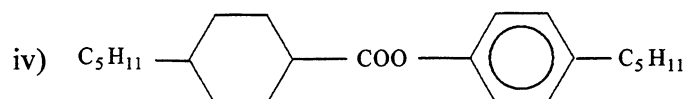
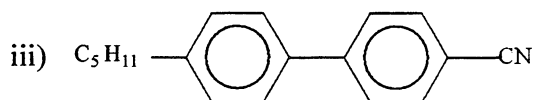
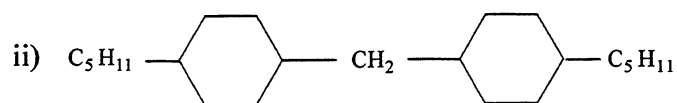
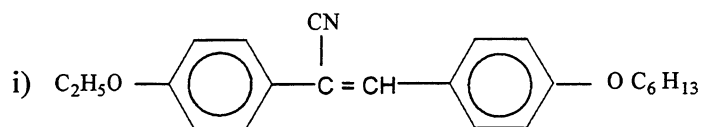
$$\Delta\varepsilon = \varepsilon_{par} - \varepsilon_{perp} = \frac{NhF}{\varepsilon_0} \left[[\alpha_l - \alpha_t] - F \left(\frac{\mu^2}{2k_B T} \right) (1 - 3 \cos^2 \beta) \right] S$$

F , N and h are constants. ε_0 is the permittivity of free space.

k_B is the Boltzman constant and T is the temperature.

Identify the parameters in this equation and give a brief explanation of the two basic terms it contains. [20%]

(d) Which one of the compounds listed below would you not expect to have a nematic liquid crystal phase? Give your reasons. [30%]



2 (a) Sketch the basic structure of a twisted nematic liquid crystal display and briefly describe its operation. Sketch its optical transfer characteristic for a normally white device. [20%]

(b) What features of this transfer characteristic control the number of pixel rows that can be electrically addressed by passive multiplexing. Give a brief explanation of your answer. [20%]

(c) State the “Iron Law of Multiplexing” first derived by Alt and Pleshko? What is the effective voltage selection ratio in a passively multiplexed twisted nematic liquid crystal display in which 20 rows of pixels are being multiplexed? [20%]

(d) Suggest at least two methods by which larger numbers of pixel rows might be addressed with improved performance? [20%]

(e) Would you expect the Iron Law to apply to a passively addressed emissive display in which each pixel was a light emitting diode? How would you suggest that such displays might be passively multiplexed? [20%]

3 (a) Describe the molecular arrangement typical of a chiral nematic (cholesteric) liquid crystal. Explain the physical features of such chiral nematic materials which make them suitable for use in thermometry. [30%]

(b) Describe the construction of a practical thermometry device based on the use of these chiral nematic materials. [30%]

(c) White light is normally incident on a chiral nematic material aligned with a planar (or Grandjean) texture. If the material has a mean refractive index of 1.6, a birefringence of 0.04 and a helix pitch of 300nm, calculate the peak wavelength of the light reflected normally. What would be the bandwidth and polarisation state of this reflected light. [40%]

(TURN OVER)

- 4 (a) Explain why, in the absence of external forces, a chiral smectic C phase is not normally ferroelectric. [20%]
- (b) Describe the principles of operation of a surface stabilised ferroelectric electro-optic device based on birefringence effects. [40%]
- (c) In order to improve the brightness of a ferroelectric device the birefringence mode of operation may be replaced by the dye-guest-host (DGH) effect. Explain how this (DGH) effect might be used to construct a light emissive display. In your explanation discuss the parameters that affect the performance of the latter device. [40%]
- 5 (a) A smectic side chain polymer film is to be used as the storage medium for optical image storage, i.e. microfiche. Describe an apparatus suitable for recording and viewing such images on the polymer film. [30%]
- (b) Explain the processes involved in selective writing and erasure of a given pixel of an optical image on such a smectic side chain polymer film. [20%]
- (c) Explain what is meant by the concept of quasi-optics in telecommunications devices using liquid crystals. [30%]
- (d) Describe an optical switch based on the concept of quasi-optics [30%]

END OF PAPER