ENGINEERING TRIPOS PART IIB

Tuesday 25 April 2006 9.00 to 10.30

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.

STATIONERY REQUIREMENTS
Single-sided script paper
Graph Paper

SPECIAL REQUIREMENTS
Engineering Data Book
CUED approved calculator allowed

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

1. (a) Describe briefly the molecular order characteristic of the nematic phase. How do domains arise and how may they be eliminated in a practical device? [30%]

(b) The elastic constants and viscosity coefficient of nematic materials all depend on the orientational order parameter S. Define S and discuss how it varies with temperature in the nematic phase and at a weak first order nematic to smectic A phase transition. Discuss the main physical parameters of a typical display device that depend on the order parameter, S. [30%]

(c) Describe an experiment that would allow the splay elastic constant of a nematic material to be measured and give the key equation that would allow the elastic constant to be calculated. [40%]

2. (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. Compare the electro-optic properties of this device with a device constructed using antiferroelectric materials. [40%]

(c) The light transmission through a ferroelectric electro-optic shutter is given by

$$I_t = I_0 \sin^2(4\theta)\ \sin^2(\pi\ \delta n\, d / \lambda),$$

where I_o and λ are the incident intensity and wavelength, respectively, θ is the tilt angle, δn the birefringence and d is the cell thickness. Discuss how the tilt angle θ and the birefringence δn vary as a function of temperature. Calculate the birefringence needed for a $\lambda/2$ waveplate if $d = 3\mu$m and $\lambda = 600$nm. What is the optimum value of θ? [40%]

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 as thermal sensors and describe the construction of such a sensor. [60%]

(b) A chiral nematic material is to be used as a narrow band reflecting mirror in a laser cavity. If the chiral nematic material has a mean refractive index of 1.5, a helix pitch of 300 nm and a birefringence of 0.03, calculate the laser wavelength and bandwidth for the reflected beam, assuming the beam is reflected normally. What would be the polarisation state of the reflected beam? [40%]

4. (a) Describe how a twisted nematic device works and discuss briefly the parameters that affect:

(i) the operating voltages and

(ii) the response time.

Give the key equations. Explain the concept of dual frequency addressing of passive matrix devices. [50%]

(b) In order to improve the light transmission of displays, polariser free, polymer dispersed liquid crystal devices have been developed. Explain the operating principles of such devices and discuss how their switching properties might be optimised. [50%]

5. (a) Dichroic or fluorescent dyes may be incorporated in so called dye-guest-host ferroelectric liquid crystal devices. Using such an effect explain how you could construct

(i) a polariser free device and
(ii) a light emissive display.

In your explanation discuss the parameters that affect the performance of the two devices. [60%]

(b) If the ferroelectric material is replaced by a nematic liquid crystal, describe how you could also construct a polariser free dichroic dye-guest-host device based on the Freedericksz transition. If such a device has a peak absorption at 632 nm and a dichroic ratio of 10:1 calculate the order parameter of the nematic material. [40%]

END OF PAPER