ENGINEERING TRIPOS PART IIB

Tuesday 7 May 2013 2 to 3.30

Module 4B20

DISPLAY TECHNOLOGY

*Answer not more than **three** questions.*

All questions carry the same number of marks.

*The **approximate** percentage 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

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) Explain what is meant by the term *coherence* in reference to an optical source of energy in a display system. Give examples of two different types of coherence commonly found in optical sources. Why is coherence an undesirable attribute in an optical source used in an image projection system? [25%]

(b) An important concept when describing the optical source in a display system are its polarisation properties. Explain how the principle of Jones calculus can be used to describe the propagation of polarised light in an optical system. What is the main limitation of this method? Does the light have to be coherent? [25%]

(c) Describe the operation of a modulation technology in a display system that depends on a fully polarised light source. Explain why this is in fact a limitation and why such a polarised light source is difficult to build in reality. Suggest two ways that this limitation could be minimised. [25%]

(d) Identify a modulation technology that does not depend on the polarisation of the light source within the display system. Explain how it works and why this leads to other limitations within the display such as grayscale and colour management. [25%]

2. (a) Explain with the aid of device schematics and band diagrams, the fundamental operating principles of the double hetero-structure organic light emitting diode (OLED). Highlight the principle differences when compared with the single-layer OLED structure. [40%]

(b) Describe, with the aid of illustrations, how the active matrix addressing for a liquid crystal display differs from that of an OLED display. [30%]

(c) With the aid of architectural schematics briefly elaborate on the benefits and trade-offs of bottom versus top emission when considering the operation of active matrix OLED display devices. [30%]

3 (a) A ray enters a prism, with apex angle α and refractive index *n*, as shown in Figure 1. Show that under certain conditions, the total angle of deflection of the ray, θ, is given by [20%]

$$\theta = (n-1)\alpha \ .$$

(b) Describe how the ray deflection angle θ leads to two very important principles in the ray tracing of an optical system. How do the conditions under which θ was derived lead to the definition of the quality of the optical system? [40%]

(c) Ray tracing is commonly used to design lenses for use in image based projection displays. Sketch the layout of an image based projector based on a single digital light projection (DLP) device and label the relevant components. Identify two major factors that dominate the design of the projection lens system. [40%]

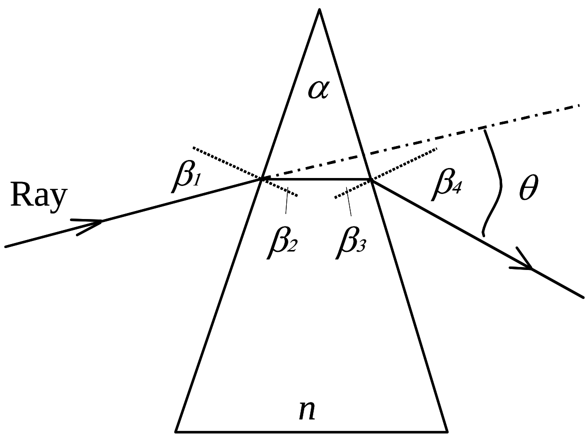

Figure 1

4 (a) Describe, with the aid of diagrams, the nematic, chiral nematic and smectic A liquid crystal phases, and explain the meaning of the terms *birefringence* and *dielectric anisotropy*. Which liquid crystal phase has the lowest degree of order? Sketch the orientational order parameter of this phase as a function of temperature. [25%]

(b) For a planar aligned nematic cell that is sandwiched between glass substrates that are coated with transparent electrodes, explain how the dielectric anisotropy affects the threshold voltage (you may assume that the dielectric anisotropy is positive). If the dielectric anisotropy is increased by a factor of four, by what fraction is the threshold voltage altered (assuming that all other properties are unchanged)? What happens if the dielectric anisotropy is negative? [25%]

(c) Using Jones Matrices show that for a planar aligned nematic liquid crystal cell that is sandwiched between crossed polarisers, the transmitted intensity can be expressed as [25%]

$$I = I_0 \sin^2 (2\phi) \sin^2 \left(\frac{\pi d \Delta n}{\lambda} \right),$$

where d is the cell thickness, λ is the wavelength of light, Δn is the birefringence of the liquid crystal, ϕ is the angle between the optic axis of the nematic liquid crystal and the transmission axis of the first polarizer and I_0 is the incident intensity before the first polarizer. You may assume that the input light is vertically polarized to match the first polarizer.

(d) Assuming that the cell is oriented relative to the polarizers in such a way that maximum transmission is obtained, simplify your expression in part (c). Find the minimum value of the cell thickness required if the incident wavelength is 550 nm and the birefringence is Δn = 0.1. [25%]

END OF PAPER