Version TDW/3

EGT3
ENGINEERING TRIPOS PART IIB

28 April 2017 9.30 to 11

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.*

Write your candidate number ***not*** *your name on the cover sheet.*

STATIONERY REQUIREMENTS
Single-sided script paper

SPECIAL REQUIREMENTS TO BE SUPPLIED FOR THIS EXAM
CUED approved calculator allowed
Engineering Data Book

10 minutes reading time is allowed for this paper

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

1 (a) Explain why pure ray theory is not sufficient to prove Snell's law. What extra information is required to solve this problem? Sketch a diagram showing an incident ray at an air/glass interface and show how Snell's law can be derived. [30%]

(b) The majority of optical elements such as lenses used in displays are designed through the process of ray tracing. Explain, using a simple positive focal length lens, how Snell's law forms the basis of this ray tracing process and show how it leads to the concept of the paraxial approximation in lens design algorithms. [30%]

(c) The paraxial ray approximation forms a limit in lens design on the performance that can be achieved. Describe three techniques that can be used to increase the performance of a lens and explain how they help avoid the limitations of the paraxial approximation. [20%]

(d) What other technique might be employed in order to avoid the limits of ray tracing when designing a display architecture? Explain why the properties of the optical source within the display is a key element in the performance of this technique. [20%]

2 (a) Sketch the layout of the transistor array for an Organic Light Emitting Diode (OLED) and a Liquid Crystal Display (LCD) when they are driven by an active matrix, showing clearly the implementation of the Thin Film Transistor (TFT) driver circuits. [25%]

(b) With the aid of a suitable diagram, showing circuitry as functional blocks, highlight the primary differences in the TFT requirements for driving an Active Matrix OLED (AMOLED) compared with an active matrix LCD. [25%]

(c) The metastable lifetime of an AMOLED display is constrained by the threshold voltage stability of the drive TFT and the luminance stability of the OLED. Assuming that the OLED luminance is proportional to the drive current and that the OLED degradation is small compared to that of the TFT, calculate the relative degradation in luminance after 1000 seconds of continuous operation.

The drive TFT is biased at V_{GS} = 5V and its initial threshold voltage V_{T1} is 2V. Its threshold voltage shift can be approximated as

$$\Delta V_T = (V_{GS} - V_{T1})\left[1 - e^{-t/\tau}\right],$$

where τ = 2000 seconds [30%]

(d) Describe how the pixel circuit can be modified in order to compensate for this degradation. What is the main penalty of this compensation? [20%]

3 (a) Describe, with the aid of diagrams, the operating principle and basic construction of a Twisted Nematic (TN) Liquid Crystal Display (LCD) pixel. Explain the meaning of the terms: threshold voltage, Mauguin limit and isocontrast curve. [30%]

(b) The transmission of a TN-LCD operating in the normally black mode can be expressed as:

$$T = \frac{1}{2}\frac{\sin^2\left(\frac{\pi}{2}\sqrt{1+u^2}\right)}{1+u^2},$$

where u is the retardation parameter.

i) Define the relationship between u and the retardance Γ for this TN mode. [15%]

ii) Sketch the Gooch-Tarry curve for the LCD and find the retardation for the first three successive minima. If the birefringence of the liquid crystal is Δn = 0.12 and the incident wavelength is λ = 532 nm, what device thickness is required to operate at either the first or second minima? When constructing a TN-LCD, which minimum is preferred and why? [35%]

(c) One of the extensions from the TN mode LCD was the Super Twist Nematic (STN) mode. Explain how the STN structure and performance differs from the TN and what particular problem it was designed to solve. Give two reasons why the STN mode failed to replace TN in later generations of LCDs. [20%]

4 (a) One of the most significant factors in analysing a projection based display is the concept of solid angle. Explain what is meant by solid angle and show that it is a critical factor in defining the brightness (or luminance) of a projection system. [30%]

(b) Using your definition of solid angle in part (a) derive an expression for the solid angle Ω, subtended by the system in Figure 1. [20%]

(c) Another design metric which can be used in projection displays, which also relates to solid angle, is étendu. Without using a mathematical derivation, describe how the étendu of an optical projector totally dictates its optical performance. [30%]

(d) A very simple projector can be built using a single Digital Micromirror Device (DMD) chip. Sketch a diagram of this single chip projector and then highlight all of the places in the system where étendu could be used to evaluate the projector performance. [20%]

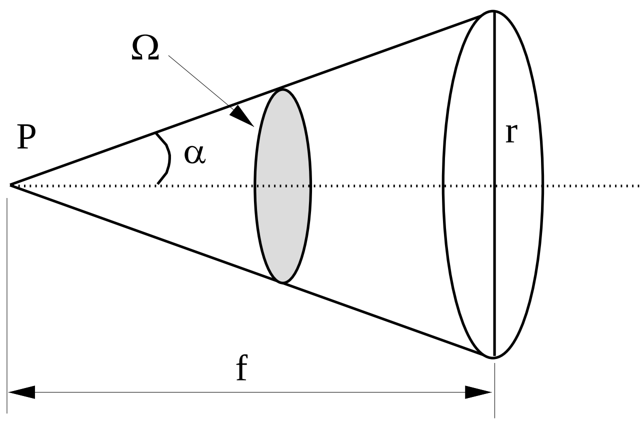

Figure 1

END OF PAPER

Numerical answers:

2(c) 37%

3(b) $\sqrt{3}$, $\sqrt{15}$, $\sqrt{33}$, 3.7 um and 7.9 um

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