COMPUTER SCIENCE TRIPOS Part Ia

Tuesday 4 June 2002 1.30 to 4.30

Paper 2

Answer the question in Section A, **one** *question from each of Sections B and C, and* **two** *questions from Section D.*

Submit the answers in five **separate** *bundles, each with its own cover sheet. On each cover sheet, write the numbers of* **all** *attempted questions, and circle the number of the question attached.*

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

SECTION A

1 Multi-part question

Answer all five parts.

(*a*) For each of the following statements, indicate whether it is true or false (there is no need to justify your answer).

(*i*) If you have a visitor from out of town you can let her check her e-mail on your University account.

(*ii*) Inebriation is a mitigating excuse if one has broken a rule governing use of University computing facilities.

(*iii*) Appropriate use of the Cambridge University Data Network and the Joint Academic Network means *bona fide* academic activity plus a low level for private purposes.

(*iv*) In Usenet newsgroup discussions your spontaneous first response to what other people say is generally the most stimulating and desirable.

[1 mark each]

(*b*) Give an example of redundancy in a safety-critical computer system. How does this affect reliability, hazards and safety? [4 marks]

(*c*) Outline the main uses of a formal specification, in the context of software engineering. [4 marks]

(*d*) Give a context-free grammar generating the language $\{a^m b^n \mid m \leqslant n\}$. [4 marks]

(*e*) Explain why care is needed when a slower sub-system is clocked from a signal generated by a faster sub-system within a digital hardware design. How can reducing the frequency of data transfers between the two sub-systems help? [4 marks]

SECTION B

2 Digital Electronics

(a) Find a minimal sum of products form for each of the following partially specified boolean functions. Each partially specified function, g_i, is specified by a function f_i which is true when g_i must be true and d_i which is true when g_i may be true or false (that is, d_i represents the "don't cares").

(i) $f_1 = y\,x\,\overline{w} + x\,y\,z + \overline{y}\,\overline{x}\,\overline{z}\,w + x\,w\,z$

$d_1 = \overline{x}\,z$ [4 marks]

(ii) $f_2 = y\,\overline{w}\,\overline{z} + \overline{w}\,\overline{x}\,\overline{z} + \overline{y}\,\overline{w}\,\overline{z}$

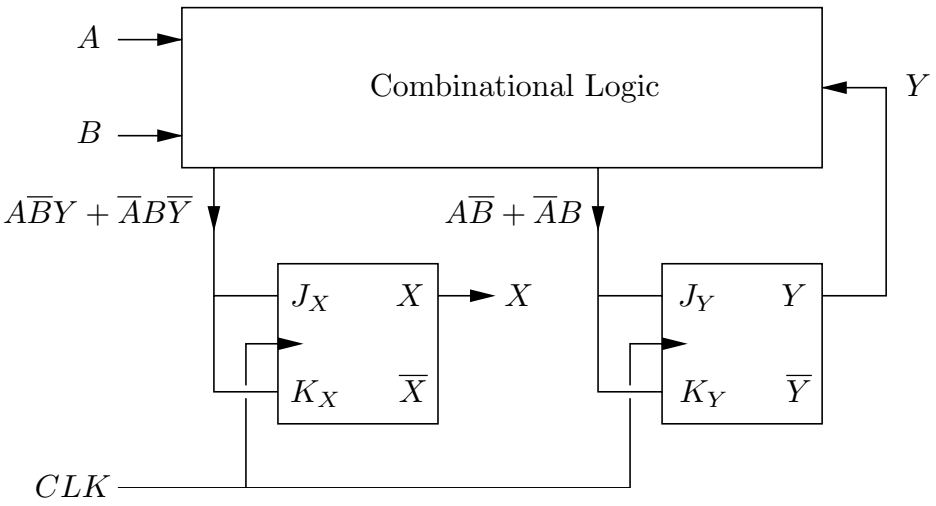
$d_2 = \overline{x}\,w\,\overline{z}$ [4 marks]

(b) What is the maximum number of product terms in a minimal sum of products form of a function of n boolean variables? [2 marks]

(c) How do "don't cares" arise in practice and how may they be exploited? Are there any pitfalls in using them? Illustrate your answer with examples. [10 marks]

3 Digital Electronics

Consider the following circuit with clock CLK, inputs A and B and outputs X and Y.



(a) How many states does this system have? [2 marks]

(b) How many rows will there be in a state transition table? [2 marks]

(c) Provide the state transition table. [8 marks]

(d) Draw a state diagram of the system. [6 marks]

(e) Describe what the circuit does in words. [2 marks]

SECTION C

4 Probability

Following a hardware practical class, an undergraduate comes across a tangle of n (single-strand) wires. After finding the $2n$ ends, he idly joins these ends together in pairs until there are no loose ends left. [At each joining, the first end is selected equiprobably from the unjoined ends and joined to a second end which is likewise selected equiprobably from the remainder.]

Another undergraduate later comes across the handiwork of the first and decides to count the number of loops in the tangle. She reasons that there could be anything from one long loop to n separate loops.

Let X_n (where $n \geqslant 1$) be a random variable whose value r (where $1 \leqslant r \leqslant n$) is the number of loops that result when the $2n$ ends of n wires are joined in pairs. Note the special case, $\mathrm{P}(X_1 = 1) = 1$. Write down a difference equation which expresses $\mathrm{P}(X_n = r)$ in terms of $\mathrm{P}(X_{n-1} = r - 1)$ and $\mathrm{P}(X_{n-1} = r)$ given $1 < r < n$ and (in consequence) $n \geqslant 3$. [8 marks]

Write down the difference equations for the special cases $\mathrm{P}(X_n = 1)$ and $\mathrm{P}(X_n = n)$. These equations should hold for $n \geqslant 2$. [4 marks]

Hence or otherwise, tabulate the distributions of the random variables X_1, X_2 and X_3 expressing all values as fractions. [5 marks]

What is the Expectation $\mathrm{E}(X_3)$, again expressed as a fraction? [3 marks]

5 Probability

An engineer has been monitoring the performance of two communication channels and has established that, on average, channel A sustains λ_A faults each month and channel B sustains λ_B faults each month. In each case a Poisson distribution may be assumed. It may also be assumed that the channels are independent.

(a) Let X and Y be random variables whose values, r and s, are the numbers of faults each month on channel A and channel B respectively. Show that the derived random variable $X + Y$ is also Poisson distributed and determine the associated parameter. [6 marks]

(b) Let $n = r + s$, the total number of faults in a given month. For given n, the engineer notes that any number from 0 to all n faults may be attributable to channel A and assumes that this number is Binomially distributed. Explain, informally, why this is a reasonable assumption. [4 marks]

(c) Noting the result of part (a), derive the parameters of the Binomial distribution which governs the random variable X *given that the total number of faults is* n. [8 marks]

(d) Supposing that $\lambda_A = 4$ and $\lambda_B = 6$, what is the expected number of faults attributable to channel A if, one month, 5 faults were recorded in total? [2 marks]

SECTION D

6 Professional Practice and Ethics

(*a*) Characterise and distinguish between consequentialist ethical theories and deontological ethical theories. Give one example of each. [4 marks]

(*b*) The first section of the new British Computer Society Code of Conduct sets out for BCS professionals six standards of how they should conduct themselves with respect to The Public Interest. State *four* of these standards. [4 marks]

(*c*) Computer security is as much a matter of institutional safeguards as it is of technical safeguards.

(*i*) Explain the two main aspects of institutional safeguards. [2 marks]

(*ii*) Name two new offences created by the Computer Misuse Act of 1990. [2 marks]

(*d*) State as accurately as you can *four* of the eight principles of the 1998 Data Protection Act and briefly explain the reason for having each of these principles. [4 marks]

(*e*) What is the difficulty in trying to claim that people have natural rights to the ownership of intellectual property such as software? Is there a consequentialist justification for maintaining ownership of intellectual property such as software? [4 marks]

7 Software Engineering I

(*a*) Compare and contrast the problems experienced in developing the London Ambulance control system with those of the Cambridge University financial accounting system (CAPSA). [6 marks]

(*b*) For *each* of these systems, describe software engineering techniques that might have been used to avoid the problems. Identify advantages and disadvantages of these techniques. [14 marks]

8 Software Engineering II

(*a*) Briefly describe top-down refinement, listing both advantages and drawbacks. [4 marks]

(*b*) How can we achieve efficiency without sacrificing reliability or programmer productivity? [3 marks]

(*c*) How can we minimise the hazards associated with memory management? [3 marks]

(*d*) In the Z specification language, what are Δ and Ξ schemas? [5 marks]

(*e*) Contrast a loop invariant with the Z concept of invariant. [5 marks]

9 Regular Languages and Finite Automata

State, with justification, whether or not each of the following languages over $\Sigma = \{a, b\}$ is regular. Any standard results you use should be clearly stated, but need not be proved:

(*a*) $\{a^m b^n \mid m, n \in \mathbb{N}\}$; [3 marks]

(*b*) $\{a^m b^n \mid m \leqslant n\}$; [5 marks]

(*c*) $\{a^m b^n \mid m + n \leqslant 4\}$; [2 marks]

(*d*) $\{w \in \Sigma^* \mid w \notin L\}$, where L is some given language which *is* regular; [4 marks]

(*e*) $\{w \in \Sigma^* \mid w \notin L\}$, where L is some given language which *is not* regular; [2 marks]

(*f*) some infinite subset of the language given in part (*b*). [4 marks]

10 Structured Hardware Design

You have been engaged as a consultant by a company which proposes to manufacture an electronic game which makes use of a grid of 10 000 pin sites, where a pin can be inserted to close a contact pair. There is an LED next to each pin site to indicate the current deployment of the player's opponent.

There is a loudspeaker for replaying spoken messages which are to be pre-recorded and built in at manufacture. There are four push buttons for controlling the game.

Sales volumes will be such that custom chips could be used throughout the product, but the chips are constrained by the low-cost assembly technology to have no more than 100 pins each.

(*a*) All the components are to be mounted on one printed-circuit board (PCB). Decide how many chips to use in the product and explain how the PCB wiring makes efficient connection to the 10 000 contact pairs and LEDs. [5 marks]

(*b*) The rules of the game must be built into the device. Comment on the factors which influence how these rules might be represented. [4 marks]

(*c*) By sketching a block diagram or otherwise, describe the remaining details of the design, including the role of memory and how audio is generated. [6 marks]

(*d*) The product should be capable of being upgraded to have networking capability via a plug-in infra red or Bluetooth module. This will enable multiple devices in the same room to communicate with each other so that multi-player games may be played. What must be added to the base product to support this option? [5 marks]

END OF PAPER