COMPUTER SCIENCE TRIPOS Part Ia

Tuesday 1 June 2004 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 parts.

(a) Name at least *four* different types of ethical theory. [4 marks]

(b) You are building a flight-control system for which a convincing safety case must be made. Would you assign the tasks of safety requirements engineering, test case development and assurance documentation to a separate team, or distribute them among your developers? Justify your answer briefly. [4 marks]

(c) Describe two particular features of ML and two (different) features of Java that might be expected to help the process of designing, implementing, debugging or maintaining high quality programs in a cost effective manner. Explain whether the features you have noted are ones that come into play for all users or if they are capabilities that a user can choose to use or to ignore. [4 marks]

(d) Draw a state diagram for a *deterministic finite automaton* that accepts $w \in \{a, b\}^*$ if, and only if, w either begins with a and is of odd length or begins with b and is of even length. [4 marks]

(e) A (ROM) Read Only Memory has 8 address inputs and 8 data outputs. Estimate how many two-input gates would be required, on average, to perform the function of the ROM. [4 marks]

SECTION B

2 Digital Electronics

The functionality of a 2-to-4 line decoder is presented in the table below.

inputs			outputs			
A1	A0	EN	S3	S2	S1	S0
X	X	0	0	0	0	0
0	0	1	0	0	0	1
0	1	1	0	0	1	0
1	0	1	0	1	0	0
1	1	1	1	0	0	0

(*a*) What are the minimum sum-of-products equations for each output of the 2-to-4 line decoder? [4 marks]

(*b*) How can five 2-to-4 line decoders be used to produce a 4-to-16 line decoder? Illustrate your answer using a circuit diagram. [6 marks]

(*c*) An LED is to be controlled via a CMOS inverter. When the input to the inverter is 1, the LED should illuminate. The on current should not exceed 20mA at which point the voltage drop across the LED will be 1.5V. What circuit should be used to control the LED? Please include resistor values. [4 marks]

(*d*) You have been asked to design the output interface for a novelty clock which represents time using just 12 LEDs. The LEDs are arranged in a circle to represent the hours on an analogue clock. You have been provided with a time-keeping component which produces a 2Hz signal and two 4 bit outputs H and M representing hours and minutes, where

$$\begin{aligned} \text{H} &= \text{h mod } 12 \\ \text{M} &= \text{m div } 5 \\ \text{h} &= \text{hours (in the range 1 to 12)} \\ \text{m} &= \text{minutes (in the range 0 to 59)} \end{aligned}$$

The LED which represents the minute is to flash at 1Hz whereas the hour LED does not flash. If the same LED is being used for both the hour and minute, it should flash. Produce a circuit diagram which meets this specification, making good use of the 4-to-16 decoder parts. [6 marks]

3 Digital Electronics

An up–down binary counter is required. There is one control input (A) and a clock (CLK). The outputs are to be labelled D0, D1 and D2. If A=1 then the counter counts up every clock period, if A=0 it counts down. Design this counter in terms of AND, OR and XOR gates, and D flip-flops. Provide equations for the outputs and a circuit diagram of the complete system. [20 marks]

SECTION C

4 Probability

A computer room is cooled by two groups of fans. Each group contains three fans. All six fans are identical and, when they fail, they fail equiprobably and independently. Two or more fans never fail simultaneously.

There is deliberate over-provision of fans so that there is adequate cooling as long as at least one fan in each group is working. The local maintenance policy is to do nothing until all three fans in one or other of the groups have failed. When that happens, all six fans in the room are replaced including those that have not failed.

(a) When replacement occurs, what is the minimum number of *working fans* that could be replaced and what is the maximum number that could be replaced? Justify your answers. [2 marks]

(b) Let X be a random variable whose value r is the number of *failed fans* when replacement occurs. Clearly $0 \leqslant r \leqslant 6$ and, for some values of r, the probability $\mathrm{P}(X = r) = 0$. By constructing an event tree or otherwise, tabulate $\mathrm{P}(X = r)$ for $r = 0, 1, 2 \ldots 6$. All non-zero probabilities should be expressed as fractions. [12 marks]

(c) Determine the expectation and variance $\mathrm{E}(X)$ and $\mathrm{V}(X)$. [6 marks]

5 Probability

A manufacturing plant consists of three machines, A, B and C, which fabricate electronic components. Machine A is responsible for 20% of the components, machine B is responsible for 30%, and machine C is responsible for 50%.

The manufactured components are supposed to be identical but it is known that 3 in every 1000 made by machine A are faulty, 1 in every 125 made by machine B is faulty, and 1 in every 250 made by machine C is faulty.

(a) An inspector selects a newly-manufactured component at random and does not know which machine fabricated it. What is the probability that it is faulty? [5 marks]

(b) A faulty component is drawn at random from a pile of rejects. Use Bayes's Theorem to determine the probabilities that the faulty component was fabricated by machines A, B and C respectively. Express your answers as fractions. [9 marks]

(c) Six faulty components are drawn at random from a pile of rejects. What is the probability that two were fabricated by machine A, two by machine B, and two by machine C? Your answer should be written as an expression which may incorporate the values determined in part (b). [6 marks]

SECTION D

6 Professional Practice and Ethics

(*a*) The professional standards of the British Computer Society's Code of Conduct are organised into four groups of standards, each including at least three specific standards. State what is the general concern of *three* of the main groups and give an example of one of the standards of conduct included in each group you mention. [6 marks]

(*b*) Suggest *two* arguments in favour of computer cracking and how one would reply to each argument. [4 marks]

(*c*) How can institutional measures serve to control computer cracking? [2 marks]

(*d*) (*i*) How can privacy exist when for virtually every fact about us there is at least one person who knows that fact? [1 mark]

(*ii*) State *two* principles of the 1998 Data Protection Act and how each serves to protect privacy. [4 marks]

(*e*) Name *three* types of law that protect intellectual property. [3 marks]

7 Software Engineering I

(*a*) Describe the spiral model of software development. [8 marks]

(*b*) Give *two* examples of software engineering tasks where it is likely to be useful, and *two* where it is less likely to be. [8 marks]

(*c*) If you were developing a security-critical system, how would you integrate the security requirements engineering and assurance processes into the model? [4 marks]

8 Software Engineering II

Explain what impact each of the following can have on reliability, development costs, programmer productivity and software efficiency:

(a) top-down refinement; [4 marks]

(b) the Z specification language; [4 marks]

(c) loop invariants; [4 marks]

(d) structural induction; [4 marks]

(e) the choice of programming language for use in a project. [4 marks]

You may wish to explain what the alternatives or opposites to the concept discussed are, or give brief examples.

9 Regular Languages and Finite Automata

(a) Prove that if L is a regular language, its complement is also regular. [6 marks]

(b) For each of the following languages over the alphabet $\{a, b\}$, state whether or not it is regular and justify your answer.

(i) $\{w \mid w$ is not a palindrome$\}$

(ii) $\{a^k \mid k$ is a multiple of 3$\}$

(iii) $\{a^k \mid k$ is prime$\}$ [14 marks]

10 Structured Hardware Design

A new scanner for small objects consists of a transmitting array of 512×512 elements and a receiving array of similar size. Each array is 4 cm on a side and the two arrays are placed 4 cm apart so that a total volume of 4^3 cubic centimetres can be scanned. Each transmitting element has two inputs that may be directly connected to digital logic and which are internally ANDed by the element.

The scanner operates in still image mode by delivering a complex pattern of microsecond resolution pulses to the transmitting array over the course of one millisecond. The more pulses that can be delivered, the better quality the image. The complete pattern of pulses is determined in advance by software. The software will be aware of any constraints you may implement in the hardware that generates the pulses.

Please execute the following steps in the design of the transmitter array:

(a) Design and sketch out the inter-wiring between the control electronics and the transmit array elements. Hence decide how many custom chips (integrated circuits) to use, taking into account a 100 pin limit for each chip. [8 marks]

(b) Decide how much RAM is needed on each chip to store the pattern and explain the data representation in RAM you have selected. Justify your decision. [4 marks]

(c) Show how the transmitting and receiving arrays may both be wired into the address space of a controlling microprocessor. [4 marks]

(d) Sketch out the internal architecture of each transmitter chip, showing the major blocks. [4 marks]

END OF PAPER