UNIVERSITY OF LONDON
IMPERIAL COLLEGE OF SCIENCE, TECHNOLOGY AND MEDICINE

EXAMINATIONS 1996

MEng Honours Degrees in Computing Part IV
MSc Degree in Foundations of Advanced Information Technology
for Internal Students of the Imperial College of Science, Technology and Medicine

This paper is also taken for the relevant examinations for the
Diploma of Membership of Imperial College
Associateship of the City and Guilds of London Institute

PAPER 4.81

MODELS OF CONCURRENT COMPUTATION
Thursday, May 16th 1996, 10.00 - 12.00

Answer THREE questions

For admin. only: paper contains
4 questions
2 pages (excluding cover page)

1a i) Show how to derive each of the following two laws of CCS from each other:

$$P + \tau.P = \tau.P$$

$$P + \tau.(P+Q) = \tau.(P+Q)$$

State any laws you use.

ii) Use equational reasoning to show that

$$b + \tau.(a + \tau.(b+c)) = c + \tau.(a + \tau.(b+c))$$

(the **O**'s are omitted.) Again, state any laws you use.

b It is desired to implement the process T defined by

$$T = a_1.(a_2.a_3.T + a_3.a_2.T)$$

Processes P_1, P_2, P_3 and S are defined by

$$P_1 = a_1.\bar{c}.f.P_1$$

$$P_2 = c.\bar{d}.a_2.e.\bar{f}.P_2$$

$$P_3 = d.a_3.\bar{e}.P_3$$

$S = (P_1 \mid P_2 \mid P_3)\backslash\{c,d,e,f\}$ (which may be abbreviated to $P_1 \parallel P_2 \parallel P_3$)

i) Draw a static diagram for S.

ii) Use the Expansion Theorem (which you need not state) to show that S = T.

2a i) Define *weak bisimulation* and *weak equivalence* ($\approx$) for CCS processes.

ii) Prove that $\approx$ is transitive.

b Show that $P \approx Q$, where P and Q are defined by

$$P = a + \tau.(b + \tau.(a + b.(\tau+c)))$$
$$Q = a + b.(\tau+c)$$

c i) Explain how *equality* of processes is defined.

ii) What does it mean for a process to be *stable*?

iii) Show that if P = Q then

P is stable iff Q is stable

The three parts carry, respectively, 40%, 30%, 30% of the marks.

3a i) State the meaning of the || operator of CSP, both informally and in terms of failures, paying attention to alphabets.

ii) Give an example to show that P||P need not be equal to P, justifying your answer briefly.

b In the Failures Model a process P must satisfy the following liveness condition:

(L) if $(s,X) \in P$ then for any $a \in \alpha P$, $(s\hat{\ }\langle a\rangle,\{\}) \in P$ or $(s, X \cup \{a\}) \in P$

Show that if P and Q satisfy (L) then so does P||Q.

c A vending machine offers tea or coffee in exchange for one coin. After the drink is vended, and before the next coin is inserted, the machine optionally adds milk for free. The machine is fair, in that it will not accept a coin unless it is prepared to vend a drink of some kind, and it will not issue a drink unless it has been paid first.

Give a failures-style specification of the machine. The events are t (tea), cf (coffee), m (milk), cn (coin).

4a i) What does it mean for a marked Petri net to be
(1) safe
(2) sequential
(3) deterministic?

ii) Four processes P_1, P_2, P_3, P_4 each alternately start up (events a_1, a_2, a_3, a_4 respectively) and shut down (events b_1, b_2, b_3, b_4 respectively). They are required to start up in cyclic order starting with process P_1. Model the system as a net, showing the initial marking.

iii) State whether your net in (ii) is
(1) safe
(2) sequential
(3) deterministic
Justify your answer.

b Consider the following two CSP processes:

$$P_1 = (a \rightarrow STOP \parallel b \rightarrow STOP) \; [] \; c \rightarrow STOP$$
$$P_2 = d \rightarrow STOP \; [] \; e \rightarrow STOP$$

i) Give event structures E_1, E_2 corresponding to P_1, P_2.

ii) Define the configuration domains C_1, C_2 associated with E_1, E_2. State which elements are complete primes.

iii) Give the configuration domain C corresponding to the sequential composition $E_1; E_2$ of E_1 and E_2.

iv) Use C to obtain the event structure $E_1; E_2$.

End of paper

