UNIVERSITY OF DUBLIN CS4B1A1

TRINITY COLLEGE

FACULTY OF ENGINEERING & SYSTEMS SCIENCES

DEPARTMENT OF COMPUTER SCIENCE

B.A. (Mod.) Computer Science **Trinity Term 2002**
Degree Examination

4BA1 INFORMATION SYSTEMS

Monday, 27th May 2002 The Mansion House 14.00–17.00

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Attempt **five** questions, at least **two** from each section.
The partition of marks is noted in the margin and correlated with effort.
Please use separate answer books for each section.
Students may avail of the HANDBOOK OF MATHEMATICS of Computer Science

SECTION A

1.

(a) Identify and briefly explain the types of constraints that can occur in a relational database management system. [6/20]

(b) Suppose a database schema consists of two relations containing information about holiday flights.

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The first relation, called Aircraft, contains an aircraft's id number (primary key), the aircraft's maximum passenger capacity, its minimum crew number requirement and the maximum distance it can travel with a full passenger list and with a full tank of aviation fuel.

The second relation, called Holiday, consists of the name of the destination country, location of the airport (city name), and the id of the aircraft which flies to that holiday destination. As there can be several holiday destinations within a country, a combination of country name and city name is used to identify a destination. Also the aircraft must exist in the database before it can be assigned to a holiday destination.

Identify and illustrate ALL the circumstances under which a relational database management system would have to check for EACH of the following types of integrity constraint violation: key, entity and referential. [6/20]

(c) Discuss how constraints based on the SEMANTICS of a relational schema can be specified in Relational Database Management Systems. Illustrate your answer using the holiday flights relational schema or an extension of that schema. [8/20]

2.

(a) Briefly describe how different occurrences of concurrency may cause transactions to interfere with each other. Give an example of each. [6/20]

(b) What is Serialisation? Explain why Serialisability is considered adequate to prove transactional non interference. [2/20]

(c) Compare and contrast (i) two phase locking which uses a deadlock prevention protocol (which you have studied) AND (ii) (pure) timestamping *as algorithms for achieving concurrency control.* In your answer outline the algorithms for two phase locking using a deadlock prevention protocol of your choice AND the algorithms involved in realising pure timestamping concurrency control. [12/20]

3. A County Council Dwellers Database stores information about people for whom they are currently providing accommodation. The system maintains information about a Dweller's name (non-unique), description (textual), date of birth and social security number (unique). The system also contains details of the dwellings themselves e.g. dwelling address, number of bedrooms, floor area of dwelling, dwelling type information. There are two attributes which make up a dwelling type, namely house type (e.g. apartment, two storey house, bungalow) and attachment (e.g. terraced, semi-detached, detached). You may assume that there are only a few legal combinations of house type and attachment type. The system also tracks which dwellers are currently habitants of which residence and the rent being applied to each residence. The rent for a particular dweller can be calculated by dividing the rent of the residence by the number of people currently residing there. The default rent for all dwellings is €1000. Note: the Council ALLOWS an individual to rent more than one dwelling.

(a) Give the functional dependency diagram for the entities represented in this database, stating any assumptions made in your answer. [4/20]

(b) Derive a relational schema for the database which is in Boyce/Codd normal form. [3/20]

(c) Write the SQL statement required to create this database, including any constraints you deem appropriate. [4/20]

(d) Write SQL statements to do the following:

(i) List the names of the dwellers who live alone.

(ii) Create a view of the dweller names, addresses and residence information.

(iii) Delete all residences where the rent is €1000. [9/20]

4. Compare and contrast, in detail, the strengths and weaknesses of OODBMS and Relational DBMSs. Your answer should include a comparison of the representational richness of their data models, information retrieval languages and performance over a range of business applications. Use examples to illustrate your answers. [20/20]

SECTION B

5. Consider a set of islands (*ISLES*) confederated to form a *nation state* of individuals (*PEOPLE*). The individuals are grouped together into households ($PEOPLE \xrightarrow{p} HH$) and households form communities called townships ($HH \xrightarrow{t} TS$). In addition the nation state has a collection of home-from-home refugee facilities (*RF*) to cater for inter-island movements, immigrants, and emigrants.

At any given time one of the islands is the *capital* island ($1 \xrightarrow{c} ISLES$) for the seat of government and is determined by strict rotation (i.e., a cyclic permutation $ISLES \xrightarrow{\sigma} ISLES$) on the date of the summer solstice fixed at the 21st day of June.

Immigrants and emigrants are welcomed at the refugee facility of the capital only and are then free to move to another island facility if they so wish. Inter-island movements occur only on the 1st day of each month.

Refugee facilities are decommissioned after a short development period (usually 3 years) and become townships. The history of the nation state has already been written (2002) from the perspective of the development of townships and their inter-relationships.

The nation state is modelled as a collection of total maps from among which we mention here:

$$f\colon TS \longrightarrow ISLES, \qquad g\colon RF \longrightarrow ISLES$$
$$\alpha, \beta, \gamma\colon RF \longrightarrow \mathbb{N}$$

where f, g denote the distributions of townships and refugee facilities and α, β, γ denote the capacity, occupancy, and availability of refugee facilities.

(a) Write mathematical expressions

(i) to compute the availability of free space γ at the refugee facilities in terms of the capacity α and occupancy β. **[Hint:** Consider the product $\langle \beta, \gamma \rangle$**].**

(ii) the refugee facility s on island k has been decommissioned. [8/20]

(b) Consider the example $f = [a \mapsto i, b \mapsto k, c \mapsto j]$ and $g = [x \mapsto i, y \mapsto i, z \mapsto j]$. Obtain the map $D \xrightarrow{h} ISLES$, where $D \hookrightarrow RF \times TS$, which gives the distribution of refugee facilities and townships in terms of g and f. [6/20]

(c) Using the example of part (b) let us suppose that the current capital is j and that $\sigma(j) = k$. Model the effect of the change of capital on refugee facility availability in anticipation of the summer solstice in 2002. [6/20]

6. The usual denotational semantics of the *assignment statement*, say $i \leftarrow v$, in imperative programming languages may be expressed quite simply by the model:

$$\sigma \in SYS = ID \longrightarrow VAL$$
$$\mathcal{M}\colon ID \times VAL \longrightarrow (SYS \longrightarrow SYS)$$
$$\mathcal{M}[i,v]\sigma := \sigma \dagger [i \mapsto v]$$

and its reification:

$$\sigma_1 \in SYS_1 = ENV \times MEM$$
$$\varrho \in ENV = ID \longrightarrow LOC$$
$$\mu \in MEM = LOC \longrightarrow VAL$$
$$\mathcal{M}_1\colon ID \times VAL \longrightarrow (SYS_1 \longrightarrow SYS_1)$$
$$\mathcal{M}_1[i,v]\langle \varrho, \mu \rangle := \langle \varrho, \mu \dagger [\varrho(i) \mapsto v] \rangle$$

(a) Suggest suitable English text for each of the following, *relevant to the features of a programming language of your choice*:

(i) $\lhd_S \sigma$ where $S \subset ID$,

(ii) $\lessdot_j \sigma$ where $j \in ID$,

(iii) $\mu(\varrho(k))$ where $k \in ID$,

(iv) $\langle \varrho \sqcup [i \mapsto a], \mu \sqcup [a \mapsto *] \rangle$ where $*$ is a special default value in VAL. [8/20]

(b) Construct an appropriate retrieve map $\mathcal{R}\colon SYS_1 \longrightarrow SYS$ and show *in broad outline* that the following diagram commutes.

$$\begin{tikzcd} SYS \arrow[r, "\mathcal{M}[i,v]"] & SYS \\ SYS_1 \arrow[u, "\mathcal{R}"] \arrow[r, "\mathcal{M}_1[i,v]"'] & SYS_1 \arrow[u, "\mathcal{R}"'] \end{tikzcd}$$

[6/20]

(c) Every (*total*) map $X \xrightarrow{f} B$ gives a fibering of the domain X over the base B. If no fiber is empty then one can take sections $B \xrightarrow{s} X$. With respect to the (*partial*) map $\varrho\colon ID \longrightarrow LOC$ construct the corresponding fibering and show how an appropriate section relates to the proof in part (b). [6/20]

7. Consider the relationship between master and disciple. In modelling this relationship we may wish to choose between *total* maps such as

$$MAST \xrightarrow{\alpha} DISC$$

$$DISC \xrightarrow{\beta} MAST$$

$$MAST \xrightarrow{\gamma} \mathcal{P}DISC$$

$$R \xhookrightarrow{\delta} MAST \times DISC$$

where δ expresses the master-disciple relation directly.

(a) Due to the nature of the master-disciple relation we note that there can not be a master without the corresponding disciple. Nor can there be a disciple without the corresponding master. Furthermore, it is an absolute requirement that any model adequately capture the notion that "no one can be the disciple of two masters at the same time". In addition, by the very nature of the master-disciple reality, it will always be the case that the number of disciples is greater than or equal to the number of masters. Let us sum up these remarks under the rubric of **the master-disciple constraint**.

(i) Let $|MAST| = m$, $|DISC| = d$ and $|R| = r$. How many maps of kind α, β, γ and δ are there?

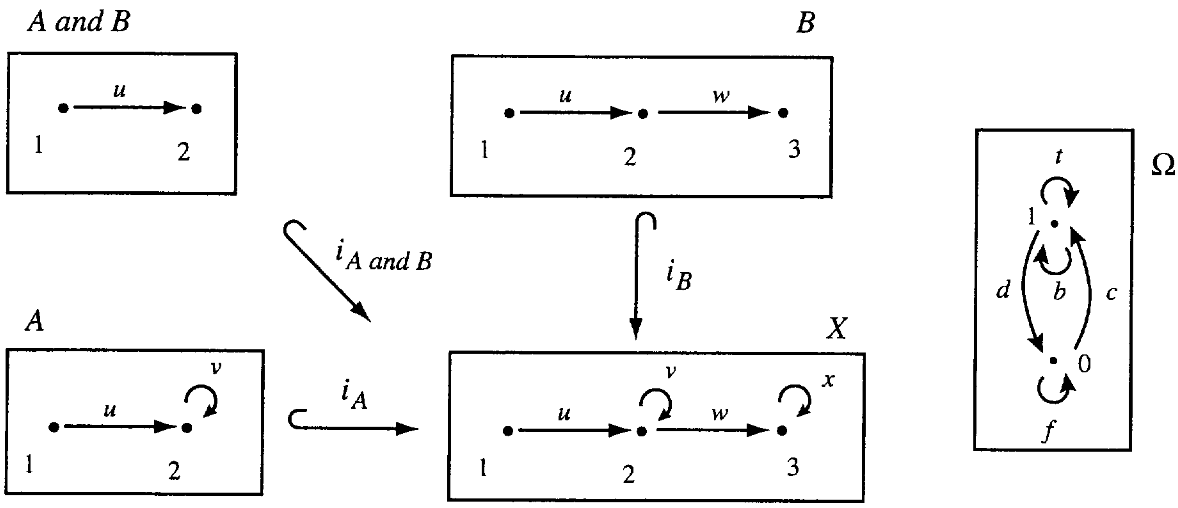
(ii) For each of the four kinds of map choose a simple example to illustrate violation of the four different aspects of the constraint. (The mapping between maps and aspects must be one to one.)

[8/20]

(b) Let us consider the model $DISC \underset{g}{\overset{f}{\rightrightarrows}} MAST$. With the aid of a simple example such as $f = [a \mapsto x, b \mapsto x, c \mapsto y]$ and $g = [a \mapsto y, b \mapsto x, c \mapsto x]$ show that we may capture the notion of state change from f to g by constructing the product $DISC \xrightarrow{\langle f, g \rangle} MAST \times MAST$. [6/20]

(c) With respect to the state change from f to g in the example of part (b) we can identify the non-change or fixed part by an *equalizer* e of f and g, $E \xrightarrow{e} DISC \underset{g}{\overset{f}{\rightrightarrows}} MAST$. Determine e and hence, or otherwise, show how one may represent the entire state change model by an object in the topos of (irreflexive directed) graphs $\mathcal{S}^{\downdownarrows}$. [6/20]

8. Consider the topos of (irreflexive directed) graphs $\mathcal{S}^{\downarrow\downarrow}$. We can imagine an object X to model part of the development of a collection of www pages. Subgraphs of X may be considered to be different possible earlier developments leading to X.



(a) Let us denote the truth-value object Ω in $\mathcal{S}^{\downarrow\downarrow}$ by the alphabet $\Sigma = \{t, b, d, c, f\}$ as illustrated above. Give details of the subobject classifiers $\varphi_A, \varphi_B, \varphi_{A \text{ and } B}$ and $\varphi_{A \text{ or } B}$ in terms of maps $E \longrightarrow \Sigma$ where E denotes the arrows/edges of the graph X. [8/20]

(b) The product object $\Omega \times \Omega$ is given by the table of 25 arrows:

	t	b	d	c	f
t	tt	tb	td	tc	tf
b	bt	bb	bd	bc	bf
d	dt	db	dd	dc	df
c	ct	cb	cd	cc	cf
f	ft	fb	fd	fc	ff

where xy denotes $\langle x, y \rangle$. Construct the map $\Omega \times \Omega \xrightarrow{\wedge} \Omega$, at least for points of $\Omega \times \Omega$. [6/20]

(c) Construct the equalizer $\leq_1$ of $\wedge$ and p_1, where p_1 is the first projection:

$$\Omega_1 \overset{\leq_1}{\hookrightarrow} \Omega \times \Omega \underset{p_1}{\overset{\wedge}{\rightrightarrows}} \Omega$$

Of what relevance might the equalizer be to the graph X and its subgraphs in the context of the development of www pages? [6/20]