Consider the following relational schema of a database that stores clinical records of the IST Lisbon Hospital:

Health-professional (professional-id, name, h-birth-date, role, salary, email, phone, performance-evaluation, start-date)
unique(email)
not null(email)

Stock (stock-id, type, service, description, quantity, delivered-date, need-to-order)

Schedule (schedule-id, professional-id, slot-start, slot-end)
professional-id: FK(Health-professional)

Patient (patient-id, name, p-birth-date)

Occurrence (patient-id, occurrence-id, type, occurrence-date, hospitalization)
patient_id: FK(Patient)

and the following tuples as examples:
Health-professional
(1, 'Catarina', 20-09-1995, ´nurse´, 1205, catarina@chlc.pt, 919999999, 20, 19-01-2021)
Stock
(0, ´needle´, ´ER´, ´2ml´ , 39 , 16-04-2021, True)
Schedule
(35, 1, 01-06-2021 00:00:00, 01-06-2021 08:00:01)
Patient
(37, ´Gervásio Lopes´, 01-01-1934)
Occurrence
(37, 40, ´Hypertension´, 19-04-2021 09:30:00, False)

Create the database in SQL Server and insert some tuples in the tables (you may want to insert the above tuples and some others)

Question 1 – SQL Server Storage and Indexing

a) Write the T-SQL command to create a database with the characteristics that follow. The database should be named IST-LH-Records. Consider the Covid-19 scenario for file growth, where at any point the number of patient records can increase exponentially, and the db should follow this growth pattern. The DB should have two data files in different filegroups,

each of them with an initial size of 23 MB. It must also have a log file with an initial size of 13 MB. The maximum size available on all the disks dedicated to the DB is 5 TB.

b) Present the T-SQL instructions to create all tables. The Occurrence table is the result of a data migration that took place on 30-04-2021 at 3 PM. This table should be partitioned so that all tuples with occurrence-date more recent than the migration date are physically stored in the secondary filegroup, and all the other tuples are physically stored in the primary filegroup.

c) Create T-SQL statements for creating one or more indexes to optimize the workload composed of the two following queries: i) get the ids of health professionals with a specific role (e.g., nurse), and ii) get the ids of health professionals older than a certain age. Explain your decision concerning the index types chosen.

Question 2 – B+ Trees

Consider that it is usual for people to ask for information about a patient based on his/her name. A B+ tree is built over the name attribute of the Patient table, holding 2 values of the search key per node. The following search key values are inserted, in the given order:

Arlindo Marques , José Oliveira, Joaquim Matos, David Jorge, Nuno Gonçalves, Daniel Mamede

a) Draw the tree after each insertion.

b) Using the final B+ tree resulting from the previous exercise, delete the following search keys, in the given order: *Arlindo Marques, José Oliveira, Joaquim Matos, David Jorge, Nuno Gonçalves, Daniel Mamede.* Present the tree after each deletion.

Question 3 – Extendable Hashing

Consider that an extendable hashing index has been created over the name attribute of the Patient table where each bucket can hold up to 2 records. Show how the following records (with the given hash values) can be stored into such index, in the given order, **considering the most significant bits first**:

José Oliveira	`10001`
Arlindo Marques	`01000`
Joaquim Matos	`00100`
David Jorge	`10001`
Nuno Gonçalves	`10010`
Daniel Mamede	`01001`

Draw the index after each insertion.

Question 4 – Query Processing and Optimization

a) Consider the Health-Professional table and a clustered B+tree over its salary attribute. Assume that this table has 729 tuples, and there are 27 records per block. Concerning the B+tree, consider that the number of pointers per node is 6. Estimate the cost of a selection (i.e., number of pages accessed), using the B+ tree index, that returns the tuples corresponding to the highest-earning professionals, that account for 132 records.

b) Suppose you are joining the Health-Professional and Schedule tables. The Health-Professional table contains 3921 pages and the Schedule table contains 24601 pages. Each page of Health-Professional can accommodate 55 tuples and each page of Schedule can accommodate 33 tuples. Compute the cost in terms of the number of I/Os (i.e., number of pages) of the following join algorithms:
    1. Indexed nested loop join, using Schedule as the inner relation and using a B+tree over professional-id on Schedule. The index tree has a height of 7.
    2. Hash-join assuming that you have 30 pages of memory and a fudge factor of 1.7. Indicate the best probe relation.

c) The first-ever child diagnosed with a new type of diabetes will be transferred to the hospital tomorrow. However, before her record is transferred, the hospital wants to check the name of the patients that have diabetes, were hospitalized in the past and were born after 2003. Write the query to obtain that information in relational algebra notation and estimate the number of tuples that result from the evaluation of the corresponding algebra expression. Consider that:
    1. The number of tuples in Patient is 10.000 and in Occurrence is 30.000.
    2. Hospitalization = {True, False} and a third of patients were hospitalized.
    3. People with records in the hospital were born between 1921 and 2021.
    4. There are 250 different types of occurrences.

Question 5 – Transactions, Concurrency Control and Recovery Management

a) Consider two transactions T1 and T2 executing operations over tables Health-professional, and Patient. Give an example of a schedule that is possible under timestamp-based protocol (with Thomas Write rule) but not possible under two-phase locking and another example that is possible under two-phase locking but not possible under timestamp-based protocol (also with Thomas Write rule).

b) Now, consider two transactions T3 and T4, where T3 writes two tuples of table Health-professional, t1(H) and t2(H), and T4 reads the same two tuples. Give an example where the timestamp test for a write operation fails and causes T3 to be restarted, in turn causing a cascade rollback of T4.

c) Consider the following simplified representation for the log file, and suppose that the ARIES algorithm is executed by the recovery system:

LSN	Type	Transaction	Page
00	Begin_checkpoint	-	-
10	End_checkpoint	-	-
20	Update	T1	P1 (Patient)
30	Update	T2	P2 (Patient)
40	Commit	T1	
50	Update	T3	P2(Patient)
60	End	T1	
70	Update	T2	P3 (Patient)
80	Abort	T2	
	CRASH!!!		

Consider also that the system crashes during the recovery process from the crash that is represented above, after having persistently written two records in the log. Assume that the active transaction table and the dirty page table are empty at the time of the checkpointing. Show the contents of the log, the active transaction table, and the dirty page table after: (a) the analysis phase, (b) the redo phase, and (c) the undo phase that are executed during the whole recovery process.

d) At the IST Lisbon Hospital, there is a schedule manager that allocates the time slots for each health professional throughout the week. However, health professionals are rebelling for working too many hours per shift without payment. So, they need to be able to register their working hours in the corresponding relation (Schedule). You agreed to help them. Nurses are all registering their hours at the same time. To manage the rebellion, the manager is actively reading the Schedule relation.
    1. Assume that each nurse transaction is running with the read uncommitted isolation level. Discuss two possible anomalies that may occur while the manager is reading the Schedule and justify.
    2. Nurse Catarina decided to help her friend and record her time. However, her friend was also registering her own time simultaneously. Show through a pair of T-SQL transactions how a phantom read can occur.

Question 6 – Database Tuning

a) Consider the Schedule and Health-professional tables. Consider that the following queries are very frequent:
    - get the names of Health Professionals
    - get the nurses' schedule

Which indexes would you create over the two tables in order to improve both queries? Justify. Perform an experimental evaluation to check if the queries use the indexes you suggested and present the corresponding execution plans.

b) Consider the following query written by the stock manager:

```
SELECT stock-id
FROM Stock s1
WHERE quantity = (SELECT avg(s2.quantity)
                  FROM stock s2 WHERE
                  s2.type = s1.type);
```

Explain the semantics of the query and show how you could rewrite it to improve its execution performance. Justify.

c) Suppose the manager wants to know, throughout the day, the name, and performance evaluation of the nurses along with their schedule slots. Suggest a schema of the database that is alternative to the one given above that could lead to better performance for the execution of this query. Justify.

Question 7 – Miscellaneous

a) Explain with your own words, the purpose of the CHECK operators proposed in the paper "Robust Query Processing through Progressive Optimization", by Volker Markl et al and published at SIGMOD 2004. Give an example of their use.

b) The paper "C-store: A Column-oriented DBMS" (SIGMOD 2005) uses the concept of **projection** in a way that is different from the way it is typically used. Explain why and give an example.

c) Pig Latin is a dataflow language proposed in 2008 by Olston et al. Explain with your own words the meaning of **dataflow language** and mention for which type of database applications this type of language is appropriate.

d) Explain how the recovery manager ensures the properties of atomicity and durability of transactions.

e) Give an example of a heuristic that an optimizer of a relational database management system can use to reduce the number of execution plans generated for a given query (and explain it).

Submitting the project

Prepare a document containing the answers to the exercises above.
Identify clearly your group number and names on the first page.
Save the document as a single PDF file and submit it to the Fénix system.
The deadline is 1/6, 23H55.
We will not accept deliveries through email.