THE UNIVERSITY of EDINBURGH

Advanced Database Systems

Spring 2026

Q&A Session 3

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About This Session

- Practice Worksheet 3 is now available on Learn
  - We will work through one question together during this session
- SQL Isolation Levels (non-examinable)
  - Why most database systems do **not** guarantee serializability by default
  - What weaker isolation levels mean in practice
  - Useful background for understanding real systems
- PostgreSQL Demonstration
  - `transaction_demo.sql` is available on Learn → Practice Worksheets
  - Run the script step by step and observe transaction behaviour

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Question 1

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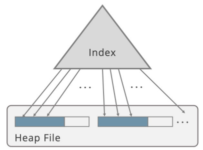
(Cost Estimation, Exam 2025) Consider a clustered B+ tree index with index entries stored using variant B, meaning that leaf nodes contain index entries in the form (key, rid). The data records are stored in a heap file, which is initially sorted.The heap pages storing the data records are 2/3 full to accommodate future inserts.



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Part (a)

I/O cost of scanning all data records

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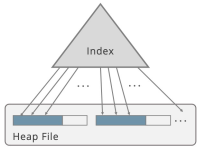

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Part (a)

I/O cost of scanning all data records

No need to use the index!

Just scan the heap file

How many heap pages exist?

- P pages when stored compactly
- But heap pages are 2/3 full

✅ Cost = $3/2 \cdot P$

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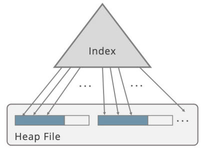

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Part (b)

I/O cost of searching on a key attribute

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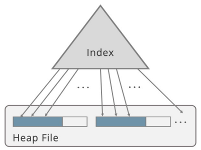

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Part (b)

I/O cost of searching on a key attribute

Scanning heap file is inefficient, better use the index *(assumed the index is on the key attribute)*

How expensive is index search?

- # of pages from root to matching leaf +
- 1 I/O to read matching data record

How many index entries of form *(key, rid)*?

- $P \cdot R$

How many leaf index pages?

- $P \cdot R / E$

What is the index height?

- $\lceil \log_F (P \cdot R / E) \rceil$

Number of pages from root to matching leaf?

- $\lceil \log_F (P \cdot R / E) \rceil + 1$

✅ **Cost =** $\lceil \log_F (P \cdot R / E) \rceil + 2$

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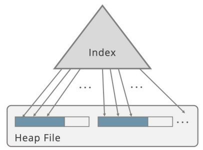

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Part (c)

Range search returning M records

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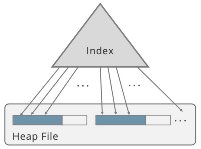

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Part (c)

Range search returning M records

To reach leaf page but not read it

$\lceil \log_F (P \cdot R / E) \rceil$

How many leaf index entries to read?

M

(strictly speaking, M+1 as you need to detect the end of range)

How many leaf index pages to read?

$\lceil M / E \rceil$

How many data records to read from heap file?

M

How many pages to read from heap file?

$\lceil 3/2 \cdot M / R \rceil$

✅ **Cost =** $\lceil \log_F (P \cdot R / E) \rceil +$
$\lceil M / E \rceil +$
$\lceil 3/2 \cdot M / R \rceil$

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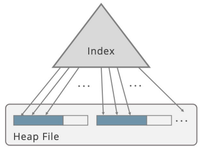

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Part (d)

Inserting or deleting one record

Assuming no changes in tree structure

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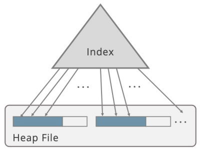

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Part (d)

Inserting or deleting one record

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Search cost: $\lceil \log_F (P \cdot R / E) \rceil$

Read leaf page → change it → write it back

Read heap page → change it → write it back

✅ **Cost =** $\lceil \log_F (P \cdot R / E) \rceil + 4$

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ISOLATION LEVELS IN PRACTICE

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Quick Recap: The 'I' in ACID

Why isolation matters

- Multiple transactions run concurrently
- Isolation controls what effects of other transactions you can see
- Without isolation, concurrent execution can produce incorrect results

Common anomalies

Anomaly	Description
Dirty Read	T1 reads uncommitted data written by T2, which later rolls back
Non-repeatable Read	T1 reads the same row twice; T2 commits an update in between
Phantom Read	T1 re-executes a range query; T2 inserts/deletes rows in between

SQL Isolation Levels

SQL-92 standard defines four isolation levels in terms of anomalies

Isolation Level	Dirty Read	Non-Repeatable Read	Phantom Read
`READ UNCOMMITTED`	Possible	Possible	Possible
`READ COMMITTED`	Not Possible	Possible	Possible
`REPEATABLE READ`	Not Possible	Not Possible	Possible
`SERIALIZABLE`	Not Possible	Not Possible	Not Possible

Key idea: Higher isolation → fewer anomalies → less concurrency

Isolation Levels in Real Systems

Most DBMS do not default to `SERIALIZABLE`

- Isolation level can be set per transaction

Why not `SERIALIZABLE` by default?

- **Serializable isolation is expensive:**
- More locking, lower throughput, more transaction aborts

What most systems choose

- Better performance + acceptable anomalies

Takeaways

- Isolation level choice is a systems trade-off among consistency, performance, and scalability
- Applications running on weaker isolation levels must explicitly handle possible anomalies

DBMS	Default Isolation Level
PostgreSQL	`READ COMMITTED`
MySQL	`REPEATABLE READ`
Oracle	`REPEATABLE READ`
SQL Server	`READ COMMITTED`
SQLite	`SERIALIZABLE`

Choosing an Isolation Level in Practice

Start with the default (`READ COMMITTED`)

- Correct for the vast majority of OLTP workloads. Most bugs are logic errors, not isolation anomalies

Use `REPEATABLE READ` for multi-step reads

- Financial summaries, audit snapshots, batch reports – anywhere two reads of the same data must agree

Use `SERIALIZABLE` when your transaction reads data to decide what to write

- Serializable is the safe default for anything involving cross-row business rules
- E.g.: "only book a seat if it's free", "only approve a transfer if the balance is sufficient"

Never set `READ UNCOMMITTED` unless you know why

- Acceptable only for approximate analytics. Dirty reads can silently corrupt business logic

PostgreSQL Demonstration

Script: `transaction_demo.sql`

- Available on Learn → Practice Worksheets

Open **two sessions** and run the script **step by step**

Observe:

- transaction behaviour
- blocking and locks
- deadlocks